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#### 4.—A new pedunculate barnacle, *Paralepas georgei* sp. nov. (Crustacea: Cirripedia-Thoracica) epizoic on Australian spiny lobsters and crabs

By A. Daniel\*

Communicated by R. W. George

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##### Abstract

*Paralepas georgei*, a new species collected in 40-80 fathoms off the southern and lower west coast of Australia, is described and discussed. Distinctive features include scuta and a carinal keel, and a distinct pectination of the mandible.

##### Introduction

During a visit to the Western Australian Museum, Perth, in 1962, opportunity availed for examining a small collection of Cirripedes, epizoic on crustaceans, which was taken for detailed study. This material included a new species of the genus *Paralepas* epizoic on lobsters and crabs.

SUBORDER LEPADOMORPHA, Pilsbry 1916.  
Family Heteralepadidae Nilsson-Cantell, 1921.  
Genus *Paralepas*, Pilsbry, 1907.

*Paralepas georgei* sp. nov. (Figs.1-10)

**Material examined:** Holotype: WAM 190-62 taken from *Panulirus cygnus* George off Rott-nest I., Western Australia (32°00'S, 115°30'E) fishing boat Gloria, 3.II.62.

**Paratypes:** Three specimens WAM 226-68 taken from *P. cygnus* off Rottnest I. (32°00'S, 115°30'E) fishing boat Gloria, 3.II.62.

Ten specimens WAM 191-62 (5 specimens) and ZSI C<sub>2</sub><sup>1</sup> (5 specimens) taken from *Jasus novaehollandiae* Holthuis, Swan I., Tasmania (40°44'S, 148°06'E) M. Olsen, 10.VIII.62.

Two specimens WAM 193-62 taken from *Pseudocarcinus gigas* (Lamarck) off Doubtful I. Bay, Western Australia (34°22'S, 119°36'E) 1.XI.59, 40-60 metres.

Twenty-one specimens WAM 196-62 taken from *Hypothalassia armata* (de Haan) 16 km. west of Rottnest I. (32°00'S, 115°30'E) K. Sheard, 22.IV.54, approx. 80 m.

**Distribution:** The above records indicate that this species of pedunculate barnacle lives in moderately deep shelf waters on the southern and lower western coasts of Australia. It is also possible that the "Lepas" mentioned by Rathbun (1923:104) on *Pseudocarcinus gigas* from Bass Strait and in the Great Australian Bight, 80-450 fathoms, also belong to *Paralepas georgei*.

**Diagnosis:** Capitulum swollen, cuticle strongly thickened, orifice crenulated, with distinct elongated scuta and carinal keel. Labrum bullate, crest hairless supporting sharp teeth, mandible with four teeth, lower and upper margins of all

four teeth (excepting upper margin of first) supporting several strong spines; first maxilla with cutting edge deeply notched, the smaller portion above notch armed with one strong spine followed by two smaller pectinated spines and the lower free margin with two large pectinated spines interspersed with paired thin spines; second maxilla elongated, superior margin with group of long setae and inferior margin with short setae. Cirri short, slightly curved with long pedicels. Each segment of cirri ii-vi with lesser curvature bearing semicircle of long and slender spines below the articulation and greater curvature bearing a semicircle of stout claw-like spines at articulation. Lesser curvature of each segment of cirri iv-vi with a pair of spinules in addition to semicircular whorl of spines. Single large filamentary appendage present at base of first cirrus. Penis distinctly annulated with minute rivet-like structures.

**Size:** The largest specimen in the collection has a capitular length of 18 mm. and a breadth of 10 mm. with the peduncle measuring 8 mm. in length and 3 mm. in breadth. The measurements of the capitulum and the peduncle in the material examined are given in the following table:—

TABLE 1

Series	Capitulum		Peduncle	
	Length in mm.	Breadth in mm.	Length in mm.	Breadth in mm.
1	18	10	8-10	3
2	12	9	10	3
3	11	8, 9	10	3
4	10	7	7	3
5	9	7	3	3
6	8	5.5-6	2-6	1.5-3
7	7	5	6	3
8	6	4-5	2-3	1.5-2
9	5	3.5-5	1.5-3.5	1.5-3
10	4	3	2-4	2-3
11	3	2	2-4	2-3

**Description:** The capitulum is extremely variable in shape. In some individuals it is laterally ovoid with smooth surface, and has a strongly arched carinal margin, and a moderately arched occludent margin which is interrupted by highly protuberant crenulated lips of slit-like orifice. The orifice extends to one-fourth the capitular length and the crenulations run inwards as distinct furrows (Fig. 1). In

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1, 2, 9  $\overline{1.0\text{ mm}}$ ; 3, 6, 7, 8  $\overline{0.5\text{ mm}}$ ; 4, 5  $\overline{100\mu}$ ; 10  $\overline{200\mu}$

Figures 1-10. *Paralepas georgei* sp. nov. 1, 2.—Entire animal, side view. 3.—Labrum with palp. 4.—Mandible. 5.—First maxilla. 6.—Second maxilla. 7.—Two segments of third cirrus. 8.—Two segments of fifth cirrus. 9.—Base of first cirrus with filamentary appendages. 10.—A few segments of penis with rivet-like structures.



some others (probably young forms) both the occludent and carinal margins are moderately arched, the former interrupted by a less protuberant orifice which extends to one-third capitular length. The lips of orifice are faintly crenulated and the crenulations slant towards base. In another series of specimens there are irregular folds on the surface with faint crenulations near the orifice. The occludent and carinal margins of the capitulum are arched equally with the occludent margin sloping into margin of orifice without interruption. The orifice is wider reaching more than one-third capitular length and capitular apex is acutely pointed (Fig. 2).

In all specimens the capitulum is greatly swollen, cuticle is strongly thickened with an inner layer of transverse muscle fibres and the orifice is slit-like, with the lips crenulated. There is a distinct carinal keel and distinct though reduced scutal plate just below the orifice.

**Mouth Parts:** The *labrum* (Fig. 3) is bullate with 30 to 40 sharp teeth borne on the hairless crest. The number of teeth varies according to the size of individuals, large specimens having more teeth. The palp is provided (Fig. 3) with several long and soft setae on inner margin. The *mandible* (Fig. 4) bears four teeth including the inferior angle. The lower margins of all four teeth and upper margins of 2nd, 3rd and 4th teeth are armed with several strong spines. The superior and inferior margins of the mandible bear numerous long and thin hair-like setae. Several rows of short and stout or long and thin spines occur near superior and inferior angles of the mandible. Spines also occur in groups or singly at the mid-region of the mandible. The *first maxilla* (Fig. 5) is divided by a prominent notch; the superior portion which is slightly less than one-third the total length of the free cutting edge bears an upper central strong smooth spine and two pectinated spines. The notch supports a few thin spines. Below the notch the cutting edge bears two major pectinated spines (equal in size to the smaller spines of the tridentate group above), interspersed with paired thin spines. The surface is clothed with numerous slender spinules and few teeth arranged in groups and rows. The superior and inferior margins bear numerous long spinules. The *second maxilla* (Fig. 6) is elongated, its superior margin supporting a group of long setae and inferior margin supporting slightly shorter setae; the space between these two groups bear 7-9 sharp teeth.

**Cirri:** The cirri are all short, and only slightly curled. The pedicels of all cirri are rather long. The number of segments in the rami of the cirri in the specimens examined is as follows:—

Cirrus i-9-10, 7-8; Cirrus ii-13-14, 15-16;  
Cirrus iii-15-16, 15-16; Cirrus iv-15-16,  
16-17; Cirrus v-14-15, 17-18; Cirrus  
vi-14-16, 17-18.

The first cirrus is inserted very near the mouth and is separate from the second cirrus. The inner rami of the first cirrus is nearly half as broad again and slightly longer than the outer rami. Both rami are densely armed with whorls of slender plumose spines. The spines

of the basal segments are straight and are plumose on both sides. The spines of the distal segments are slightly curved with the greater curvature being plumose.

The cirri ii to vi are nearly equal in length. The inner rami of cirri ii and iii are slightly broader than the outer rami, while in the cirri iv to vi the rami are nearly equal in width.

Each segment of the cirri ii to vi exhibits the armature typical of the subgenus *Paralepas*. The lesser curvature of the segments support a semi-circle of long and slender spines (the longest pair of spines being plumose on one side) below articulation (Fig. 7). In cirri iv to vi, in addition to these spines, each segment bears a pair of spinules below the semicircular whorl of spines (Fig. 8). The greater curvature of the segments of cirri ii to vi supports at each articulation a semi-circle of stout, claw-like spines.

At the base of the first cirrus there is a single large filamentary appendage (Fig. 9). At the base of the sixth cirrus there is a caudal appendage; it has seven to twelve segments and is a little longer than the protopodite of the sixth cirrus. The penis is long, tapering, distinctly annulated, has minute, rivet-like structures placed along its length (Fig. 10), and also bears long setae and short spines scattered over surface and at tip.

**Remarks:** Newman (1960) following the suggestions of Pilsbry (1907), Annandale (1909) and Broch (1922) raised the subgenera *Heteralepas* Pilsbry and *Paralepas* Pilsbry to the generic level. The genus *Paralepas* Pilsbry is considered to include the following valid species and forms: *P. dannevigii* (Broch, 1922), *P. distincta* (Utinomi, 1949), *P. globosa* (Hiro, 1936), *P. intermedia* (Hoek, 1907), *P. lithotryae* (Hoek, 1907), *P. minuta* (Phillipi, 1836) and subspecies *americana* (Pilsbry, 1953), *P. morula* (Hoek, 1907), *P. nodulosa* (Broch, 1922), *P. palinuri* (Barnard, 1924) and subspecies *urae* (Newman, 1960), *P. pedunculata* (Hoek, 1883), *P. pericarinata* (Pilsbry, 1907), *P. reticulata* (Annandale, 1914), *P. rosea* (Hiro, 1938), *P. tuberosa* (Nilsson-Cantell, 1932), *P. xenophorae* (Annandale, 1906), and *P. scyllarusi* Utinomi, 1967.

The present species can be separated from all these species excepting *P. dannevigii* (Broch) by the presence of both scuta and a carinal keel. *P. dannevigii* (Broch) which also possesses a pronounced carinal keel and chitinous scuta occurs in deep water on gastropods and differs conspicuously in the mandible being armed with small denticles on the lower side of the third tooth only, the maxilla having a relatively lesser pronounced notch with strong spine at upper edge and the penis with a tuft of hairs at the distal end and a few rather short hairs on sides.

The present species resembles *P. palinuri urae* Newman (1960, fig. 6 G.), *P. distincta* Utinomi (1949, fig. 2 D), *P. lithotryae* Hoek (1907, pl. ix, figs. 8-8') and *P. scyllarusi* Utinomi (1967, fig. 2 d) by the possession of a broad tapering and coarsely annulated penis which is furnished with many rivet-like structures.

The present forms differ conspicuously from all the known species of *Paralepas* in the distinct pectination of the mandible i.e., the lower

margins of all four teeth and upper margin of 2nd, 3rd and 4th teeth supporting several strong spines, several rows of short and stout or long and thin spines occurring near superior and inferior angles and also the occurrence of spines in groups or singly at the midregion of the mandible. The first maxilla also is distinct by the possession of an upper central smooth strong spine and two smaller pectinated spines below, with the deep notch supporting a few thin species and cutting edge below notch bearing two large spines which are pectinated and surface of maxilla clothed with numerous slender spines and few teeth arranged in groups and rows. The lesser curvature of each segment of cirri iv-vi, in addition to supporting a semicircle of long and slender spines (of which the longest pair are plumose on one side), bears a pair of spinules. This is also a peculiar feature. Hence it is treated as a new species, *Paralepas georgei*.

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#### References

- Annandale, N. (1906).—Natural history notes from the R.I.M.S. ship "Investigator", Capt. T. H. Heming R.N. Commanding. Series III No. 12. Preliminary report on the Indian stalked barnacles. *Ann. Mag. Nat. Hist. Ser. 7*, Vol 17, 100.
- (1909).—An account of the Indian Cirripedia Pedunculata. Pt. I, Family Lepadidae (s. str.) *Mem. Indian Mus.* 2(2): 51-137.
- (1914).—New and interesting Pedunculate Cirripedes from Indian seas. *Rec. Indian Mus. Calcutta*, 10: 273-280.
- Barnard, K. H. (1924).—Contributions to the Crustacean fauna of South Africa, No. 7. Cirripedia. *Ann. S. Afr. Mus.* 20(1): 1-103.
- Broch, H. J. (1922).—Studies on Pacific Cirripedes. Papers from Dr. Th. Mortensens Pacific Expedition 1914-16, No. 10. *Vidensk. Medd. Dansk. naturh. Foren. Kjobenhavn*, 73: 215-358.
- Hiro, F. (1936).—Descriptions of three new species of Cirripedia from Japan. *Bull. Biogeogr. Soc. Japan*, 6(23).
- Hoek, P. P. C. (1883).—Report on the Cirripedia collected by the H.M.S. "Challenger" (Zool.) 8(25): 1-169.
- (1907).—The Cirripedia of the Siboga-Expedition Pedunculata. Siboga-Expedite, 31a: 1-127.
- Newman, W. A. (1960).—Five Pedunculate Cirripedes from the Western Pacific, including two new forms. *Crustaceana* 1(2): 100-116.
- Nilsson-Cantell, C. A. (1921).—Cirripeden-Studien. *Zool. Bldr. Uppsala*, 7: 75-395.
- (1927).—Some barnacles in the British Museum, *Proc. Zool. Soc. London*, (3): 743-790.
- (1932).—Cirripeden aus Japan. *Ark. Zool.*, Bd. 24 A (4).
- Pilsbry, H. A. (1907).—The Barnacles (Cirripedia) contained in the collections of the U.S. National Museum, *U.S. Nat. Mus. Bull.* 60, 1-X, 1-122.
- (1953).—Notes on the Floridan Barnacles (cirripedia). *Proc. Acad. Nat. Sci. Philad.* 105: 13-28.
- Rathbun, M. J. (1923).—Report on the crabs obtained by F.I.S. "Endeavour". *Biol. Res. Endeavour* 1909-1914, 5: 95-156.
- Stubbings, H. G. (1965).—West African Cirripedia in the collections of the Institut Francais d'Afrique Noire, Dakar, Sengal Bull. de e'. I. F.A.N. 22, Ser. A. (3): 896-907.
- Utinomi, H. (1949).—Studies on the Cirripeden fauna of Japan VI. Cirripeds from Kyusyu and Ryukyu Islands. *Publ. Seto. Mar. Biol. Lab.* 1(2): 19-37.
- Utinomi, H. (1958).—Studies on the Cirripeden fauna of Japan VII. Cirripeds from Sagami Bay. *Publ. Seto Mar. Biol. Lab.* 6(3): 282-311.
- Utinomi, H. (1967).—Occurrence of a new Pedunculate Cirriped on a small spanish lobster *Scyllarus bicuspidatus* (De Man) from Kamae Bay, North eastern KYUSYU. *Publ. Seto. Mar. Biol. Lab.*, 15(2): 117-120.
- Zullo, V. A. and Newman, W.A. (1964).—Thoracic Cirripedes from a southeast Pacific Guyot. *Pacific Science*, 28(4): 355-372.



## 5.—Alpha-activity of Western Australian soils and wheats

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### Abstract

Lateritic soils formed on the Precambrian shield of south-western Australia have measured  $\alpha$ -activities in the range 40-100 pCi/g from naturally occurring isotopes; whereas in soils formed on Mesozoic and Cainozoic coastal sediments the  $\alpha$ -activity seldom exceeds 20 pCi/g.

The ash activity of wheat growing on the more active soils can be as high as 90 pCi/g. However, there is at least a three-fold variation in uptake of active isotopes depending on wheat variety.

For the lateritic soils there is a correlation between total  $\alpha$ -activity and both ironstone gravel content and the total Fe + Al in the soil. There is also some evidence for an activity dependence on present climate and rainfall.

Although applied superphosphate fertilizer is high in natural radio-activity it is not believed to have made a significant contribution to the measured  $\alpha$ -activity of the soil.

### Introduction

The first measurements by Marsden (1961) of natural  $\alpha$ -activity in Western Australian wheats and soils, from samples taken at Wongan Hills and Merredin, indicated unusually high levels of  $\alpha$ -emitting isotopes when compared with samples taken elsewhere (Marsden, 1960; Mayneord, Turner and Radley, 1960; Zymłowska and Wilgain, 1961; Zymłowska and Ostrowska, 1965).

From independent samples we have confirmed the high values reported by Marsden and have extended the range of observations to an additional thirty-five sites in the southern half of Western Australia.

Our interest in  $\alpha$ -activity in Western Australian soils stems from two sources:

- (1) the use of natural radio-activity as a tool for studying the absorption by plants of trace amounts of elements from soils. In particular it is expected that root exploration and the physical nature of the root/soil interface may be studied by following the absorption of certain nuclides.
- (2) The measurements of isotopic ratios which may be used as indices of weathering (Talibudeen, 1964). The use of isotopic ratios is of particular interest, because large areas of Western Australia are characterised by well developed laterite profiles in which the dominant minerals are sesquioxides of iron and aluminium. It is known that thorium tends to accumulate with the sesquioxides (Talibudeen, 1964) and therefore, comparison of the Th/U ratio

in the laterites and their parent materials should provide a sensitive index of the weathering processes involved.

As a preliminary to these investigations however, it is necessary to measure total levels of  $\alpha$ -activity and where possible correlate these levels with various plant and soil factors such as geological parent material, soil type, rainfall and leaching, clay mineral type and content, sesquioxide abundance, wheat variety and calcium content of soil and plant. The first results of this broad survey are presented in this paper.

### Experimental Technique

Samples of topsoil and subsoil were collected from 35 sites in the south-west of Western Australia during July, 1966.

Included in these samples were soils from Wongan Hills and Merredin, two of the sites sampled by Marsden. The remaining localities were selected primarily for major differences in geological parent material and are shown in figure 1. Where fresh rock outcrops occurred near the site, they were also sampled.

If available, data was also recorded concerning superphosphate history and wheat variety.

Phosphate rock and superphosphate samples were collected from the two major distributors in Western Australia. Marsden (1959) has reported that phosphate rock is high in  $\alpha$ -activity and because of the high rates of application of superphosphate on wheat growing soils in Western Australia it was necessary that the contribution from this source to the natural radio-activity should be determined.

Before measuring the  $\alpha$ -activity levels, the soil and rock samples were dried in a 110° C oven and crushed to pass a 120 mesh sieve, and the separated wheat grain was ashed overnight at 600-650° C and again crushed to pass a 120 mesh sieve.

Particle size analyses were carried out on all the soil samples by screening through 10 mesh and 120 mesh sieves and the  $< 2\mu$  clay fraction was separated by sedimentation. For a limited number of soil samples the  $\alpha$ -activities of the gravel fraction, and the clay fraction were measured individually.

The detection and measurement of  $\alpha$ -particles emitted from these powdered samples followed very closely the technique described in detail by Turner, Radley and Mayneord (1958). Basically, the sample was contained in a shallow translucent tray, one surface of which was coated with a finely divided scintillating phosphor. The powdered sample was in intimate contact with the phosphor and sealed into the tray to prevent loss of radon. A period of 3-4

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TOWNS DESIGNATED BY ○ BORDEN  
 SITES DESIGNATED BY ● 2



Figure 1.—Location of  $\alpha$ -activity sampling sites in south-western Australia.

weeks was allowed to elapse before counting to allow radon and thoron daughters to reach equilibrium.

The scintillations from the phosphor were detected by a 5 in. photomultiplier and the resulting pulses, after amplification and discrimination were fed to a fast electronic scaler. Because the counting rates were comparatively low, dead-time losses were negligible.

In the thorium series disintegration chain,  $Rn^{220}$  emits an  $\alpha$ -particle and decays to  $Po^{216}$  which again decays by  $\alpha$ -emission to  $Pb^{212}$ . Since the half life of  $Po^{216}$  is 0.158 seconds, these successive emissions will be detected as pairs

of  $\alpha$ -particles with an average separation of approximately 0.2 seconds. For unweathered geological materials, where it can be assumed that the thorium series is in equilibrium, then the 'pairs' rate will give an accurate measure of the thorium concentration in the sample (Cherry, 1963). Further, for the thorium series

in equilibrium the ratio of counts to pairs ( $\frac{C}{P}$  ratio) as determined by Cherry (1963) is 16.4 and he has shown that an increase in the value of this ratio may be used to determine the concentration of uranium in the sample.



For soils or plant materials where weathering or preferential uptake of certain nuclides has disrupted the equilibrium of the thorium and uranium series it is not possible to measure thorium or uranium concentrations in this way. However, the thorium 'pairs' rate and  $\frac{C}{P}$  ratio can still yield important information.

If for example, the  $\frac{C}{P}$  ratio is significantly greater than 16.4 then either uranium is present in the sample, or there is a depletion of some of the daughter elements in the thorium series. The two possibilities may be distinguished by measuring those coincidence counts occurring in the time intervals 3.6 milli-seconds which are characteristic of the double  $\alpha$ -decay of the isotopes  $Rn^{219}$ , and  $Po^{215}$  (half life 1.83 milli-seconds) of the uranium decay series.

If the  $\frac{C}{P}$  ratio is significantly less than 16.4 this would indicate that the samples contain few, if any, of the head members of the thorium series.

In order to measure the uranium and thorium 'pairs' two fast mechanical registers and two co-incidence gates were interposed between the amplified pulse output and the electronic scaler. The mode of operation was as follows:—A pulse leaving the amplifier would be counted by the electronic scaler and would also activate the first coincidence gate for a period of 3.6 milli-seconds (two half-lives of  $Po^{215}$ ). A second pulse arriving within this time interval would be recorded on both the electronic scaler and on the 'uranium pairs' register. After 3.6 milli-seconds the first coincidence gate would close and the second gate would open, remaining active for a period of 316 milli-seconds (two half lives of  $Po^{214}$ ). A second pulse arriving within this time interval would be recorded by the electronic scaler (total counts) and on the 'thorium pairs' register.

Before the total  $\alpha$ -activity and the thorium and uranium concentrations could be calculated, where applicable, it was necessary to know the mean atomic number  $\bar{Z}$  (Turner, Radley and Mayneord, 1958) and mean atomic weight  $W$  (Cherry, 1963) of the sample material.

In the case of wheat ashes a combination of wet chemical and X-ray fluorescence analysis was used to obtain  $Z$  and  $W$ , and for the parent rocks these values were calculated from published analyses of similar rock types (Mason, 1958).

For many Western Australian soils, major element analysis has shown that there is an excellent correlation between  $Z$  or  $W$  and the iron and calcium content of the soil. For these soils therefore, calcium and iron were measured by flame emission and absorption techniques respectively and the corresponding values of  $Z$  and  $W$  were determined.

Exchangeable calcium was measured using molar  $NH_4Cl$  to displace the calcium which was then determined on the S.P. 900 flame photometer.

The major clay and accessory minerals in the  $< 2\mu$  fraction were analysed qualitatively using a Phillips X-ray powder diffractometer.

Full details of these analyses will be presented in a later publication.

#### Calculation of $\alpha$ -activity

The total  $\alpha$ -activity in curies per gram (Ci/g) of each sample was calculated from the equation developed by Turner *et. al.* (1958), and is given by

$$\frac{A}{T} = \frac{C}{R_0 \cdot A \cdot \bar{Z}^{\frac{3}{2}}} \cdot 9.4 \times 10^{-11} \text{ Ci/g} \quad (1)$$

where  $C$  = counts/hour above background

$R_0$  =  $\alpha$ -particle range in cm. of standard air.

$A$  = area of sample in  $cm^2$ .

For unweathered rocks, in order to calculate the concentrations of uranium and thorium from the pairs counts it was necessary to allow for the chance occurrence of 'spurious pairs'.

This correction was carried out from the equation proposed by Cherry (1963) where the spurious pairs rate  $S$  is given by

$$S = C^2 \cdot \tau \exp(-N_0 \cdot \tau) \quad (2)$$

where again  $C$  = total count rate

and  $\tau$  = dead time of the register circuit

The half life correction, as discussed by Cherry was applied to the corrected pairs rate to obtain a final value,  $P$ , for the pairs rate, in this case disintegrations occurring in two half lives were measured, yielding  $\frac{3}{4}$  of the total 'pair' disintegrations, therefore the half life correction factor was 1.333.

Having determined the pairs rate  $P$  and the total  $\alpha$ -count rate  $C$  (both in counts/hr) the thorium and uranium concentrations in p.p.m. for the rock samples were calculated from the equations

$$C = W^{\frac{1}{2}} \cdot A (0.155 U + 0.0434 Th) \quad (3)$$

$$P = W^{\frac{1}{2}} \cdot A \left[ \frac{Th}{378} \right] \quad (4)$$

where  $A$  = area of sample

$W$  = means atomic weight of sample

The derivation and limitations of equations (3) and (4) have been fully discussed by Cherry (1963).

For the soils and ashed wheats, as previously discussed, equations (3) and (4) do not apply

and for these samples  $\frac{C}{P}$  ratios have been calculated instead.

Tables 1, 2 and 3 list these results for soil, ashed wheat and rocks respectively.

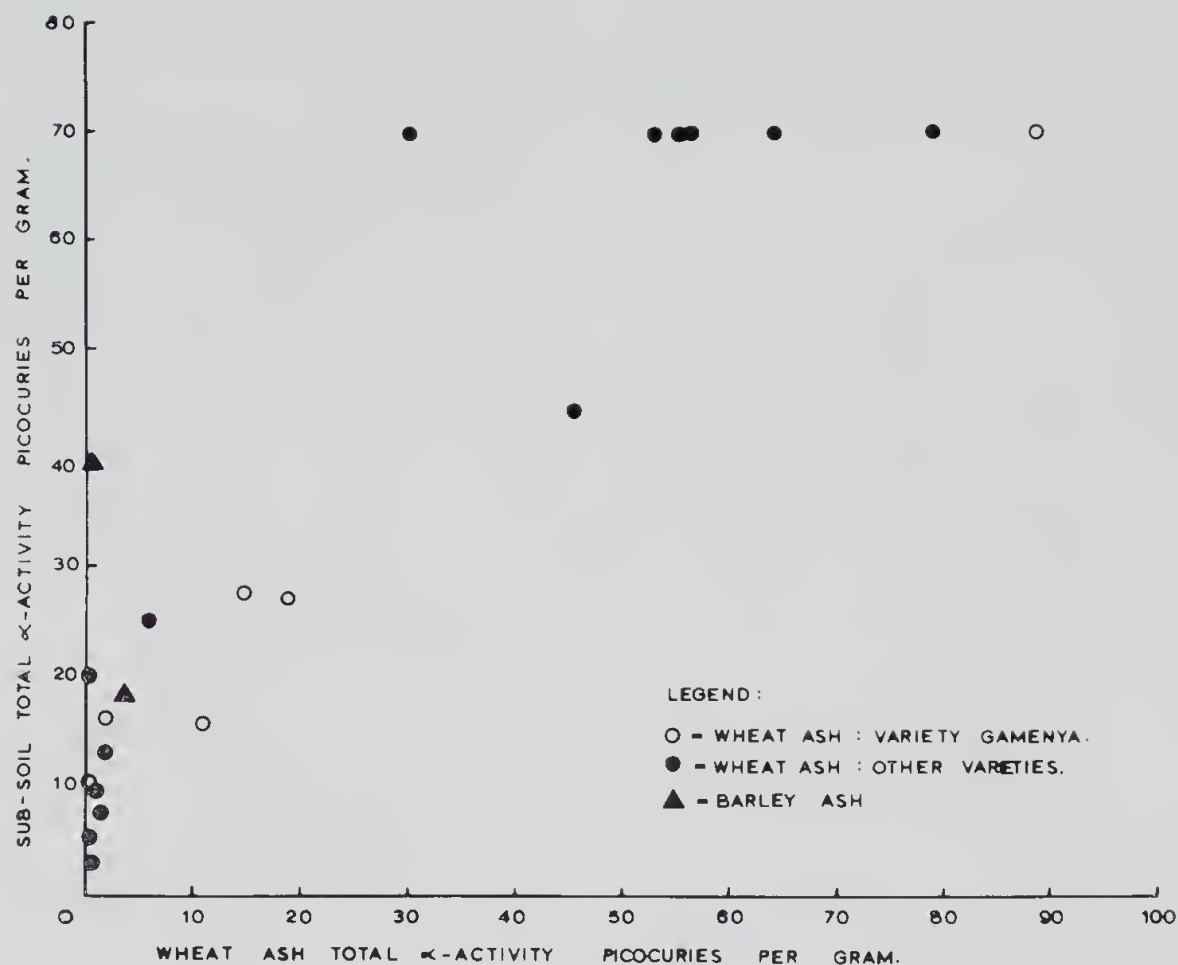


Figure 2.—Correlation of wheat-ash and soil  $\alpha$ -activity.

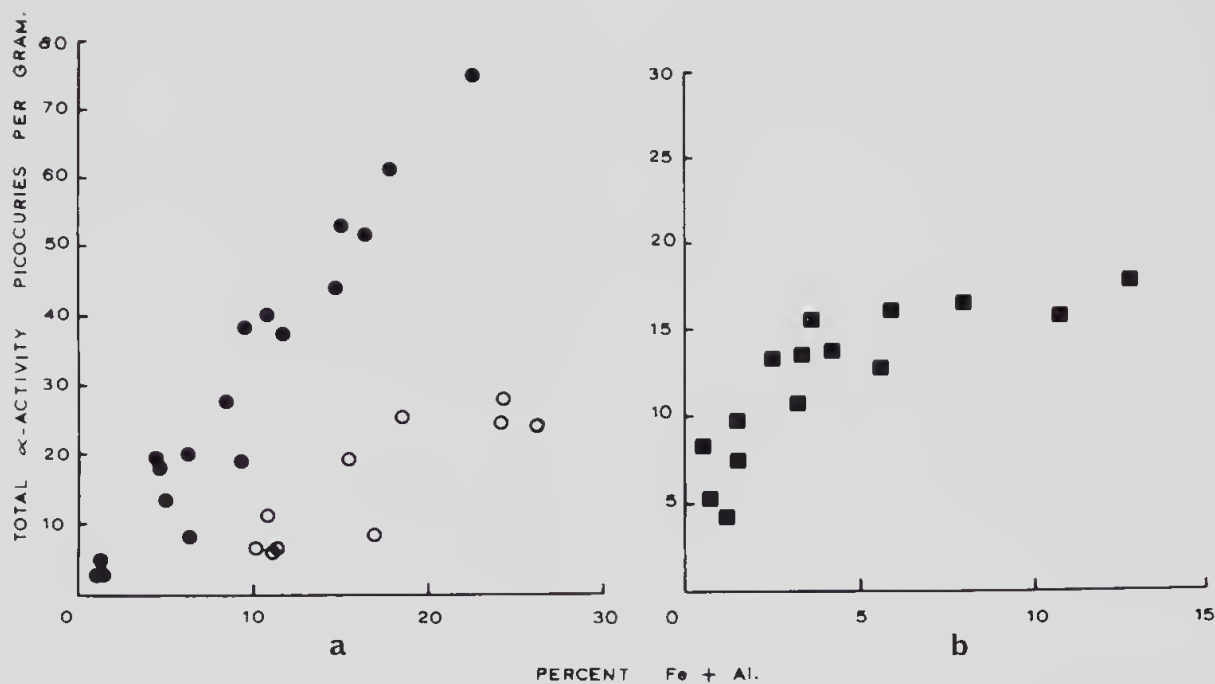


Figure 3.—Correlation of soil  $\alpha$ -activity with per cent, Fe + Al. 3a.—Total  $\alpha$ -activity of soils formed on the Pre-Cambrian Shield of Western Australia; • = soils of lateritic origin; o = other soils. 3b.—Total  $\alpha$ -activity of soils formed on Mesozoic and Cainozoic sediments.

### Experimental results and discussion

From the data presented in Tables 1, 2 and 3 the following points were noted.

(i) Soils and wheats from the western part of the Precambrian shield were in general much more active than those from other localities measured in this survey, and elsewhere.

(ii) Although the ashed wheat activities were obviously dependent on the activity of the soil on which they were growing, Fig. 2, the correlation was much poorer than expected. This can be partially explained by the wide variation in uptake of  $\alpha$ -emitting isotopes by wheats of different varieties as shown in Table 2 for site 10 at Wongan Hills. For these seven wheats, growing on the same soil there was a three-fold increase in the ash activity from the lowest to the highest respectively.

(iii) It has been stated that thorium tends to accumulate with sesquioxides of iron and aluminium (Talibudeen, 1964). Considerable difficulty was experienced in quantitatively extracting these sesquioxides from the soil samples and therefore a correlation was attempted between total  $\alpha$ -activity and the sum of total iron and aluminium as measured on the atomic absorption spectrophotometer. The results are shown in Fig. 3. For those soils which are mainly of lateritic origin (closed circles Fig. 3a) there is a linear correlation, however in the second group (open circles Fig. 3a) the association between  $\alpha$ -activity and percent Fe + Al is not as obvious. All the soils in this group are fine textured, therefore much of the aluminium will be present in the clay fraction rather than as sesquioxide. In addition, most of these soils contain finely divided fresh rock fragments and several were formed on or near basic dolerite

intrusions which would contribute to the high Al and Fe contents without a proportionate increase in total  $\alpha$ -activity.

For the soils formed on Cainozoic and Mesozoic sediments the total  $\alpha$ -activity is approximately proportional to the logarithm of the percent Fe + Al. This departure from linearity may be explained in a similar way, in that the more active soils contain a higher proportion of clay which in turn contains appreciable amounts of aluminium.

(iv) For soils formed on the Precambrian shield the  $\alpha$ -activity levels of the sand and gravel components were often higher than the finer fractions as shown in Fig. 4a, where there is a definite negative correlation between total soil activity and percent soil passing a 120 mesh sieve. The soils formed on Cainozoic and Mesozoic sediments are by contrast low in  $\alpha$ -activity and tend to exhibit a positive correlation with percent soil passing a 120 mesh sieve (Fig. 4b). Two soils from sites 18 and 19 (open circles Fig. 4a) do not fit this general scheme. Although formed on Precambrian granite rock and of coarse texture they are extremely low in  $\alpha$ -activity. The soils at both of these sites have undergone severe leaching and consist mainly of coarse grains which apparently cannot retain active isotopes. For the five samples listed in Table 4 the gravel activity  $A_G$  was measured separately and the activity of the remainder of the sample  $A_R$  was calculated from the equation:

$$A_R = \frac{A_T - A_G \cdot x_G}{1 - x_G} \quad (5)$$

where  $A_T$  = total activity of the sample  $x_G$  = weight fraction of gravel.

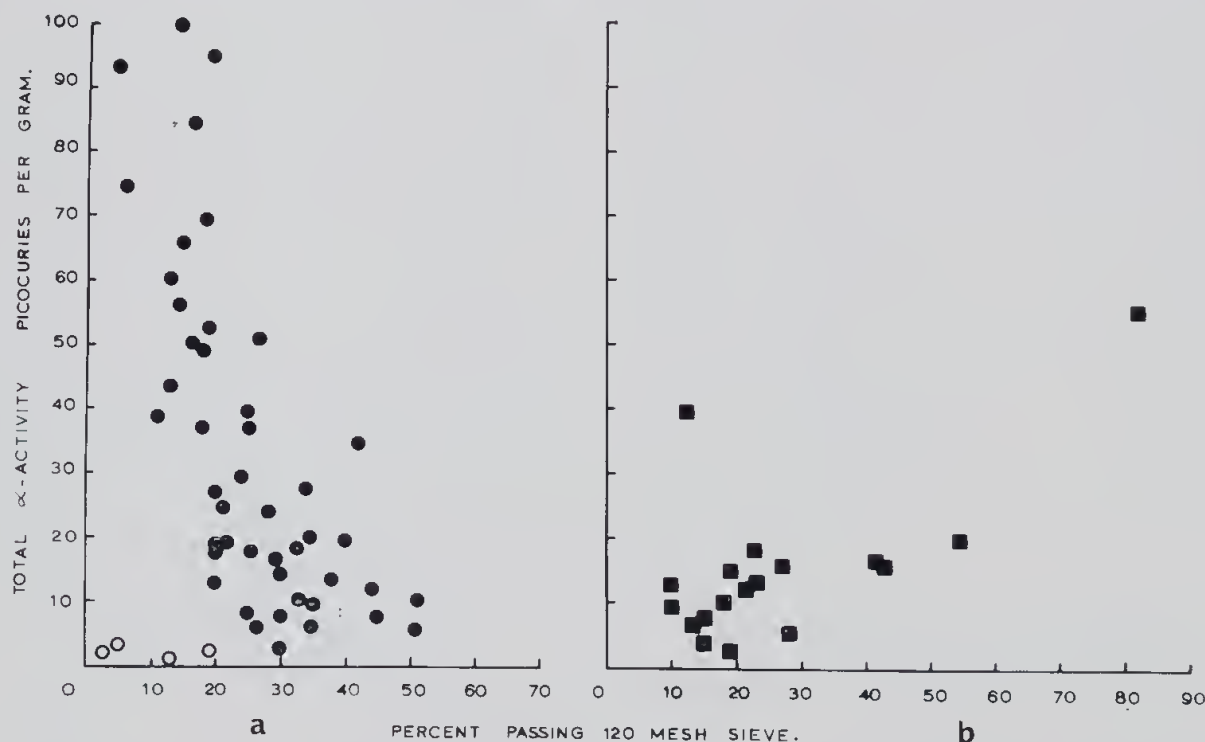


Figure 4.—Correlation of soil  $\alpha$ -activity with particle size. 4a.—Total  $\alpha$ -activity of soils formed on the Precambrian Shield of Western Australia; o = samples from sites 18 and 19. 4b.—Total  $\alpha$ -activity of soils formed on Mesozoic Cainozoic sediments.



TABLE 1

Table 1.—Total  $\alpha$ -activity of surface and sub-soil samples.†

Site No. and Location	Sample No.	Depth Sampled	Gravel %	Geological Substrate	Total $\alpha$ -activity pCi/g	C/P	Munsell Colour
1. Irwin	1.1	0-12"	0	M.S.*	20	23	7.5 yr 4/2
2. Irwin	2.1	0-7"	0	M.S.	8	22	10 yr 4/1
	2.2	7-20"	0	M.S.	7	30	10 yr 6/3
3. Greenough	3.1	0-12"	0	M.S.	4	24	10 yr 3/3
	3.2	12-20"	1	M.S.	3	22	5 yr 6/3
4. Eradu	4.1	0-5"	0	M.S.	11	20	2.5 yr 4/4
	4.2	5-15"	0	M.S.	16	34	2.5 yr 5/6
	4.3	15-20"	0	M.S.	13	20	2.5 yr 5/6
5. Eradu	5.1	0-4"	0	M.S.	10	24	10 yr 6/2
	5.2	4-20"	0	M.S.	13	20	7.5 yr 6/6
6. Tenindewa	6.1	0-6"	3	M.S.	16	26	2.5 yr 3/6
	6.2	6-24"	4	M.S.	16	17	2.5 yr 3/8
7. Pindar	7.1	0-6"	10	A.G.	27	33	10 yr 6/4
	7.2	6-20"	66	A.G.	75	29	10 yr 7/6
	7.2.5**	6-20"	....	A.G.	81	17	....
8. Cama	8.1	0-4"	8	A.S.	19	16	5 yr 4/6
	8.2	4-16"	29	A.S.	25	20	2.5 yr 3/6
	8.2.5	4-16"	....	A.S.	40	16	....
9. Wongan Hills	9.1	0-4"	0	A.G.	19	22	2.5 yr 6/2
Sampled Aug. '66	9.2	4-12"	8	A.G.	19	20	2.5 yr 7/4
	9.3	12-17"	41	A.G.	37	28	....
	9.4.3	12-17"	....	A.G.	45	19	....
Sampled Nov. '66	9.6	0-4"	....	A.G.	18	26	....
	9.7	4-12"	....	A.G.	20	26	....
	9.8	12-17"	....	A.G.	34	20	....
	9.9	0-4"	....	A.G.	55	....	....
	9.10	4-8"	....	A.G.	34	....	....
10. Wongan Hills	10.1	0-5"	16	A.G.	66	20	10 yr 7/2
	10.2	4-10"	20	A.G.	70	16	....
	10.2.2	4-10"	....	A.G.	66	24	....
	10.2.5	4-10"	....	A.G.	83	16	....
	10.3	10-20"	47	A.G.	60	29	2.5 yr 5/6
	10.4	0-4"	....	A.G.	85	12	....
	10.5	4-8"	....	A.G.	95	15	....
	10.6.5	Surface Gravel	....	A.G.	172	15	....
11. Calingiri	11.1	0-4"	45	Dolerite Dyke	29	26	2.5 yr 5/4
	11.1.5	0-4"	....	Dolerite Dyke	33	15	....
	11.2	4-15"	20	Dolerite Dyke	28	28	2.5 yr 5/6
11. Calingiri	11.3	15-22"	17	Dolerite Dyke	25	30	2.5 yr 3/6
12. Kellerberrin	12.1	0-4"	5	A.G.	18	15	10 yr 5/1
	12.2	6-14"	56	A.G.	44	17	2.5 yr 7/2
	12.2.5	6-14"	....	A.G.	53	17	....
	12.3	14-28"	3.5	A.G.	51	27	10 yr 7/6
13. Merredin	13.1	0-3"	1	A.G.	49	16	7.5 yr 5/4
	13.2	3-14"	8	A.G.	52	16	5 yr 5/4
14. Southern Cross	14.1	0-8"	0	A.G.	37	14	2.5 yr 4/4
	14.2	8-27"	8	A.G.	40	17	5 yr 5/8
15. Bulong	15.1	0-10"	27	A.S.	6	17	5 yr 6/3
	15.2	10-20"	32	A.S.	3	13	5 yr 6/4
16. Norseman	16.1	0-2"	16	A.S.	8	17	7.5 yr 5/4
	16.2	2-10"	25	A.S.	8	36	7.5 yr 6/4
	16.3	10-22"	8	A.S.	11	28	5 yr 5/3
17. Dowak	17.1	0-3"	0	M.S.	14	21	7.5 yr 5/4
	17.2	3-20"	10	M.S.	14	21	....
18. Esperance	18.1	0-24"	0	A.G.	3	27	5 yr 8/4
	18.2	24-48"	0	A.G.	4	18	2.5 yr 8/6
	18.3	48-60"	21	A.G.	39	17	10 yr 5/6
19. Dalyup	19.1	0-8"	0	A.S.	2	20	2.5 yr 6/2
	19.2	8-30"	0	A.S.	2	21	2.5 yr 8/2
20. Ravensthorpe	20.1	0-5"	53	A.S.	8	20	5 yr 5/3
	20.2	5-12"	6	A.S.	10	18	5 yr 5/6
21. Ongerup	21.1	0-4"	0	A.G.	13	14	10 yr 5/1
22. Borden	22.1	0-6"	0	A.S.	5	18	5 yr 5/3
	22.2	6-14"	0	A.S.	5	20	10 yr 7/3
	22.3	14-24"	0	A.S.	12	10	2.5 yr 4/6
23. Borden	23.1	0-3"	9	A.S.	6	22	5 yr 3/4
	23.2	3-12"	2	A.S.	11	13	2.5 yr 3/4
	23.3	12-16"	2	A.S.	6	12	7.5 yr 7/6
24. Albany	24.1	0-4"	44	M.S.	17	22	10 yr 5/1
	24.2	4-16"	76	M.S.	40	17	10 yr 7/3
	24.2.5	4-16"	....	M.S.	30	23	....

\* M.S. = Mesozoic and Cainozoic marine sediments.

A.S. = Archaean Sediments with basic igneous intrusives.

A.G. = Archaean granite.

\*\* Sample number with two digits only, were prepared by grinding to pass a 120 mesh sieve.

Third digit =  $2 < 2\mu$  fraction.

3 mottles separated and ground.

5 gravel separated and ground.

† The exact locations of the above samples sites are available from the authors.

TABLE 1 (Continued)

Table 1.—Total  $\alpha$ -activity of surface and sub-soil samples.†

Site No. and Location	Sample No.	Depth Sampled	Gravel %	Geological Substrate	Total $\alpha$ -activity pCi/g	$\frac{C}{P}$	Munsell Colour
25. Jarrahwood .....	24.3	16-26"	16	M.S.	57	27	10 yr 6/6
	25.1	0-6"	0	M.S.	5	22	10 yr 7/1
	25.2	6-15"	17	M.S.	14	17	2.5 yr 7/2
	25.3	15-30"	53	M.S.	18	67	
26. Capel .....	26.1	0-24"	....	M.S.	52	....	
34. Wongan Hills .....	34.1	0-4"	0	A.G.	51	7	
	34.2	4-8"	0	A.G.	17	21	
	34.3	8-16"	43	A.G.	49	17	
	35.1	0-4"	47	A.G.	56	17	
35. Wongan Hills .....	35.2	4-8"	79	A.G.	94	29	
60. Corrigin .....	60.1	0-3"	42	A.G.	101	....	
61. Corrigin .....	61.1	20-24"	65	A.G.	282	....	
62. York .....	62.1	0-2"	....	A.G.	39	....	
	62.2	2-8"	....	A.G.	46	....	

† The exact locations of the above samples sites are available from the authors.

The last column of Table 4 lists the ratio  $\frac{A_G}{A_R}$ , from which it can be seen that the gravel fraction was generally higher in activity than the remainder. Sample 24.2 was an exception; however in this sample the coarse material mainly consisted of rounded pieces of magnetic haematite, in contrast to the concretionary ironstone gravels in the other samples.

For these ironstone gravels the uranium pairs  $\frac{C}{P}$  count rate was negligible and the  $\frac{C}{P}$  ratios were

in the range 15-17 which is characteristic of the  $Th^{232}$  decay series in equilibrium. Some caution must be exercised in interpreting these  $\frac{C}{P}$

$\frac{C}{P}$  ratios however, because recent experiments, using a new counting technique to determine true pairs directly, indicate that the Poisson distribution used by Cherry (1963) over estimates the spurious pairs at high count rates. Further work is required before a better correction can be established with any degree of precision.

(v) The contribution from superphosphate application to the total  $\alpha$ -activity of a soil was estimated from measurements of the activity of eight batches of superphosphate produced by CS-BP and CRESCO, the two leading distributors in Western Australia (Table 3). A mean for the superphosphate activity was 63 pCi/g and for a typical application rate (180 lbs/acre) the increase in soil activity at the surface would be 30 pCi/sampling area (250 cm<sup>2</sup>). If, for example, as the result of ploughing or leaching, this activity was distributed through only the top 10 cm of soil, then the increase in soil activity would be of the order 0.01 pCi/g. The general conclusion may be reached then, that even prolonged applications of superphosphate fertiliser at high rates will not cause a measurable increase in soil  $\alpha$ -activity.

At Wongan Hills, sites 9 and 10, a comparison of soils which had received heavy applications of superphosphate (samples 9.1, 9.2, 9.3, 10.1, 10.2, 10.3) and of the same soils which had received no superphosphate (samples 9.6, 9.7, 9.8, 10.4, 10.5) showed the activity levels to be comparable or even higher in the unsupered soils, thus supporting this general conclusion. A possible exception was encountered at site 11, Calingiri, where a shallow clay-loam soil has developed directly on a dolerite dyke. In this soil, activity levels of approximately 30 pCi/g were encountered whereas the activity of the

TABLE 2

Table 2.—Total  $\alpha$ -activity of ashed wheat and barley.

Site No. and Location	Wheat Variety	Total $\alpha$ -activity pCi/g	$\frac{C}{P}$
1. Irwin .....	....	<1	23
2. Irwin .....	....	2	30
3. Greenough .....	....	1	19
4. Eradu .....	Bungulla	11	59
5. Eradu .....	*Gamenya	....	....
6. Tenindewa .....	Insignia	2	23
7. Pindar .....	Gamenya	2	21
8. Canua .....	Gamenya	19	27
10. Wongan Hills .....	Falcon	6	42
Wongan Hills .....	Gamenya	65	....
Wongan Hills .....	Gamenya	90	18
Wongan Hills .....	Gabo	80	17
Wongan Hills .....	Benubbin	56	34
Wongan Hills .....	Noongar	31	46
Wongan Hills .....	Insignia	55	34
Wongan Hills .....	Wagin	54	17
11. Calingiri .....	Gamenya	15	61
12. Kellerberrin .....	....	46	57
20. Ravensthorpe .....	....	1	23
21. Ongerup .....	*	4	32
22. Borden .....	....	<1	9
23. Borden .....	Gamenya	<1	9
24. Albany .....	*	<1	20
27. Wyalkatchem .....	Gabo	8	22
28. Nungarin .....	Insignia	2	43
27. Benubbin .....	....	4	33
30. Morawa .....	Falcon	2	14
31. Northampton .....	Mengarvie	1	21
32. Northampton .....	Gamenya	<1	23
33. Lake King .....	....	9	33
60. Corrigin .....	....	69	....

\* Barley Ash.

TABLE 3

Table 3.—Total  $\alpha$ -activity of rocks and superphosphate.

Site, Location or Source	Sample	Total $\alpha$ -activity pCi/g	C P	U ppm	Th ppm
9. Wongan Hills	Archaean Granite	65	34	12	40
11. Calingiri ..	Dolerite	4	24	<1	3
16. Norseman ...	Archaean Gneiss	7	40	1	4
18. Esperance ....	Proterozoic Granite	59	21	4	60
24. Albany .....	Limestone	20	15	0	29
Senegal .....	Phosphate Rock	218	42	...	...
Florida ...	Phosphate Rock	348	23	...	...
Naurn Island	Phosphate Rock	191	...	...	...
Togoland	Phosphate Rock	252	...	...	...
Ocean Island	Phosphate Rock	184	...	...	...
Xmas Island	Phosphate Rock	47	...	...	...
Cresco, Perth	Superphos- phate '65-'66	59	35	...	...
Cresco, Perth	Nov. '66	74	66	...	...
Cresco, Perth	Feb. '62	51	50	...	...
CS BP, Es- perance	'65-'66	55	31	...	...
CS BP, Al- bany	'65-'66	66	33	...	...
CS-BP, Perth	'63-'64	71	26	...	...
CS BP, Perth	'64-'65	72	34	...	...
CS BP, Perth	'65-'66	54	24	...	...

parent dolerite was only 4 pCi/g. Here it would seem that one or more components in the soil has the ability to 'fix'  $\alpha$ -active isotopes from the applied superphosphate.

The increasing use of highly active Florida rock phosphate in Western Australian superphosphates from 1966-67 onwards may clarify this situation for subsequent samplings.

(vi) at site 9, Wongan Hills, a series of soil measurements at yearly intervals since 1965 has indicated that the rate of movement of  $\alpha$ -active isotopes through the soil profile may be much faster than is generally supposed. Topsoil and subsoil taken late in 1965 whilst the site was in crop were quite active, 55 pCi/g and 34 pCi/g for the 0-4 in. and 4-8 in. sample respectively (samples 9.9 and 9.10) which are comparable with values measured by Marsden (private communication). After lying fallow for a year the

TABLE 4

Table 4.—Comparison of total  $\alpha$ -activity of the whole soil with that of the gravel component.

Sample	Weight Fraction Gravel $\times$ g	Total Activity A T (pCi/g)	Gravel Activity A G (pCi/g)	Remainder Activity A R	$\frac{A}{A_R}$ $\frac{G}{R}$
7.2	0.66	81	83	78	1.1
8.2	0.29	27	41	22	1.9
10.2	0.35	71	86	63	1.4
12.2	0.56	45	54	33	1.7
24.2	0.78	43	33	78	0.4

site was re-sampled in 1966 and again in 1967. For these samples (9.1, 9.2, 9.3) there was a significant decrease in surface activity. However, at a depth which coincided with a zone of soft iron concretions and clay mottlings the activity was again quite high. The inference then, is that ploughing throws active materials into the surface soil and this subsequently leaches back to the sesquioxide horizon. Further detailed sampling will be required to confirm this point.

(vii) From the measurements of  $\alpha$ -activity made so far, it is difficult to make conclusive statements regarding the effects of climate and rainfall, however, the following observations appear to be pertinent.

On an easterly transect through York, Kellerberrin, Merredin and Southern Cross to Bulong and Norseman there is a steady decrease in mean rainfall from 18-20 in. to 9-10 in. Eastwards as far as Merredin, which lies close to the 12 in. isohyet, the dominant soils are coarse textured yellowish loamy sands with much iron-stone gravel, and the soil  $\alpha$ -activity is reasonably constant in the range 45-50 pCi/g.

Further eastwards the activity diminishes sharply to 2-10 pCi/g (Bulong and Norseman) and the soil becomes a finer textured gravel-free reddish clay-loam with a much more uniform distribution of iron through the profile. Therefore it would appear from the present results that when the mean annual rainfall is sufficient to cause waterlogging in winter and favour gravel formation then there is also a concentration of  $\alpha$ -active isotopes.

Further south, at Esperance and Dalyup in the 25 in. rainfall belt, with a more uniform distribution of rainfall throughout the year the soils are more severely leached, contain negligible amounts of Fe and Al and are extremely low in activity.

### Conclusions

Lateritic soils formed on the Precambrian shield of Western Australia are unusually high in natural  $\alpha$ -activity and there is a definite association between activity levels and the ironstone gravel content of the soils. For these soils there is also a significant correlation between activity and Fe + Al content.

Some of the active isotopes present in the soil are readily taken up by wheat, however the rate of uptake varies widely with variety.

Although superphosphate fertiliser is high in natural  $\alpha$ -activity it is unlikely at normal application rates to have made a significant contribution to the total soil activity.

There is some evidence that leaching of active isotopes through the soil profile may be quite rapid in regions of adequate rainfall and there appears to be an association between soil activity levels and rainfall and climate.

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#### References

- Cherry, R. D. (1963).—*Geochim. Cosmochim. Acta* 27: 183.  
 Marsden, E. (1959).—*Nature*, Lond. 183: 924.  
 ——— (1960).—*Nature*, Lond. 187: 192.  
 ——— (1961).—*Nature*, Lond. 189: 326.
- Mason, B. (1958).—'Principles of Geochemistry' 2nd Ed. (John Wiley and Sons Inc., New York).  
 Mayneord, W. V., Turner, R. C. and Radley, J. M. (1960).—*Nature*, Lond. 187: 208.  
 Talibudeen, O. (1964).—*Soils Fertil. Harpenden* 27: 347.  
 Turner, R. C., Radley, J. M. and Mayneord, W. V. (1958).—*Br. J. Radiol.*, 31: 397.  
 Zymłowska, S. and Ostrowska, A. (1965).—*Roczniki glębzn.* 15: 203  
 Zymłowska, A. and Wilgain, S. (1961).—*Nukleonika*. 6: 813.

## 6.—Notes on the Flora and Vegetation of the Nullarbor Plain at Forrest, W.A.

By E. R. L. Johnson\* and A. M. Baird†

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### Abstract

Brief collecting trips to Forrest in the centre of the Nullarbor Plain were made in 1930 and 1955, years in which above average rainfall had resulted in exceptionally rich development of the herbaceous flora. One hundred and five species of flowering plants were collected, of which twenty-two were introduced.

The flora is composed mainly of taxa which are common to the floras of the drier inland regions to the west and east of the Nullarbor Plain. A few only extend further to the south west and south east into regions with higher rainfall. Dominant families are Chenopodiaceae, Asteraceae and Poaceae which, in addition to having the largest number of species, more than half the total, also produce an abundance of individual plants. Introduced plants were not abundant and were found only near the railway line and aerodrome.

The representation of families is typical of the Eremaea and in contrast with that of the south western corner with its abundance of Myrtaceae, Proteaceae and Epacridaceae.

The vegetation is described under the headings: plain, depressions and tree belt. The greatest number of species was found in the "dongas", broad shallow depressions which had a few large shrubs usually *Acacia oswaldii*, *Eremophila longifolia* and *Pittosporum phylliracoides*; clumps of low perennials and a seasonal ground cover of grasses and herbaceous dicotyledons. On the main level of the Plain the open dwarf shrub community of *Kochia sedifolia*, the "bluebush" characteristic of the Nullarbor Plain, was seen in healthy condition in 1955, only in restricted areas. In many places old dead stems were all that remained, with the shorter lived *Bassia*s forming the sparse ground cover. A belt of Myall trees (*Acacia soudeii*), 14 miles north of Forrest, was in poor condition in 1955 with most of the trees dead.

The general impression in the area is of a perennial vegetation near the limit of tolerance of the arid climate, and unable to withstand the additional pressure of rabbit grazing.

### Introduction

The Nullarbor Plain, that vast featureless stretch of country lying north of the Great Australian Bight (fig. 1) has been known since early days of exploration, and since 1917 has become familiar to the thousands of travellers on the trans-continental railway. Nevertheless there is no detailed botanical description of the central Nullarbor. It is an arid area with average annual rainfall between 6 and 7 inches (160 mms) and shade temperatures which may exceed 110°F in any of the summer months (but there is no shade on the Plain!). Geologically it forms part of the Eucla basin of horizontally bedded tertiary (Miocene) limestone and the soil is shallow, reddish calcareous loam.

Early explorers described it as a "dreary waste" and "stony waterless desert" and most of them were content to journey around its edges. However, Tate (1879), while searching for artesian water, went inland about 33 miles from Eucla and reached its southern part. He noted the sparseness of the vegetation and that species were few. Willis (1959), in an account of explorers and collectors in the Eucla region, mentions Delisser (1861 and 1865), Batt (1886-1896) and Kemsley (1952) as having collected plants from parts of the Plain. Willis with the Russell Grimwade expedition, 1954, collected between the head of the Bight and Madura. Anketell in 1901, when a member of Muirs Trans-Australian Railway Survey Team, collected 22 species (now in the Western Australian Herbarium). As localities were not attached to some of these, it is doubtful how many were found on the Plain.

In South Australia a number of collections have been made on the eastern edge of the Plain near Ooldea by Capt. A. S. White (Black 1917), Cannon (1921), Black (1921), Ising (1921), Adamson and Osborn (1922) and on the Plain at Hughes, 32 miles east of the Western Australian border, by Ising (1920). Adamson and Osborn described the vegetation of the Nullarbor Plain as shrub steppe with *Kochia sedifolia* and *Atriplex vesicaria* as the principal shrubs. They also described the vegetation of the "dongas", a term of South African origin which has been accepted in the literature and in local usage for depressions scattered throughout the Plain.

Forrest, lat. 30.5 S, long. 128.06 E. lies in the centre of the Plain and therefore, as far as the flora is concerned, should show a minimum of influence from surrounding regions. The authors visited this locality for 3 days in October, 1955, in the expectation of seeing the herbaceous vegetation in good condition after above average rains. An equally brief trip had been undertaken in 1930, so there was interest in comparing the vegetation 25 years later. The photographs and descriptions are of the vegetation as seen in 1955 except where the early visit is specified. Collecting was done within easy walking distance of the aerodrome and railway and on trips by truck north and south of the line which gave a cross section nearly 30 miles long (sketch map, fig. 2).

The first impression of the vast flat Plain stretching unbroken to the horizon is unforgettable. The flatness is, however, relative and in detail the Plain is undulating and with widely scattered depressions of varying extent and depth. Several of these were visited and also a belt of trees about 14 miles north.

\* C/o State Herbarium of South Australia, North Terrace, Adelaide, S.A. 5000.

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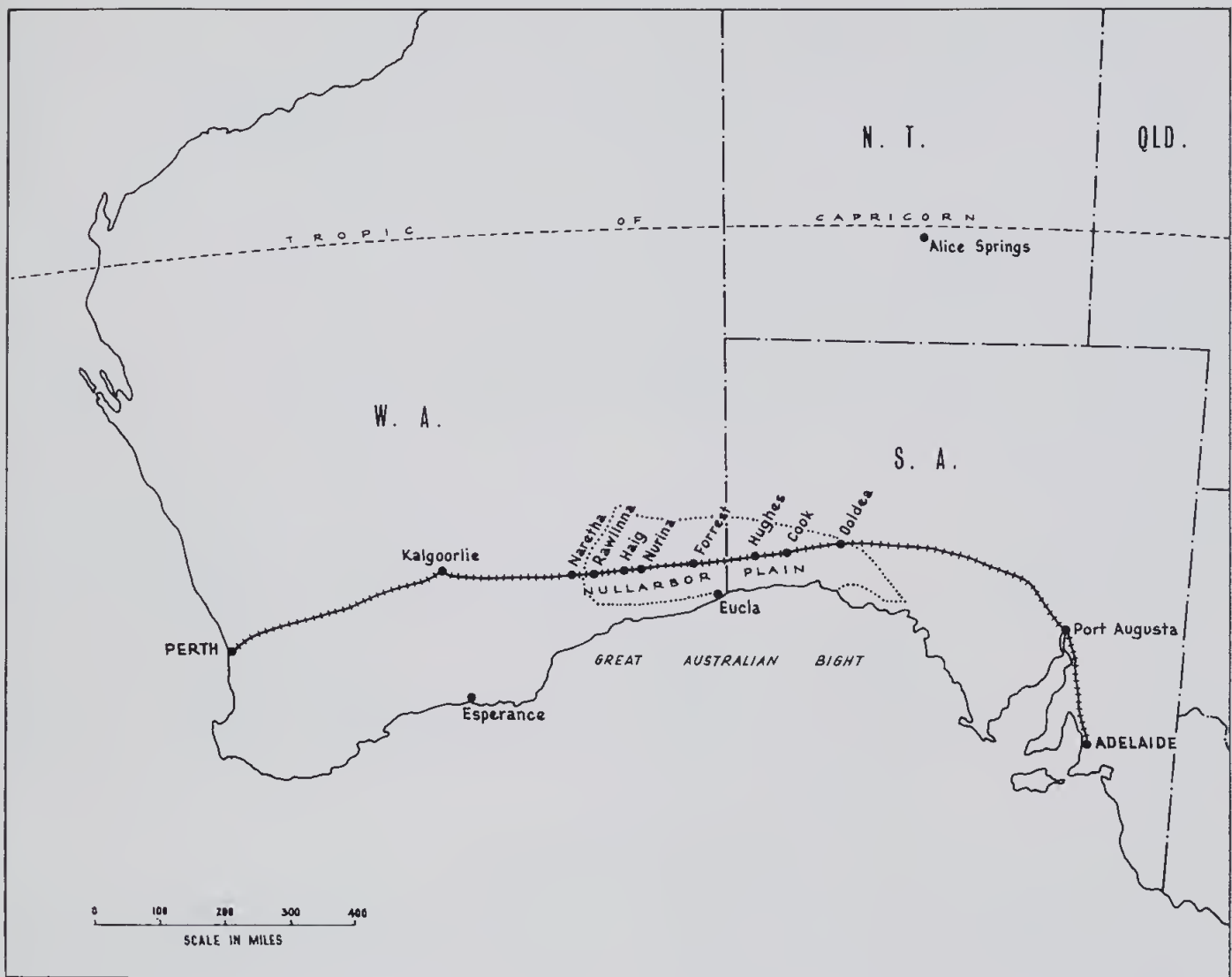
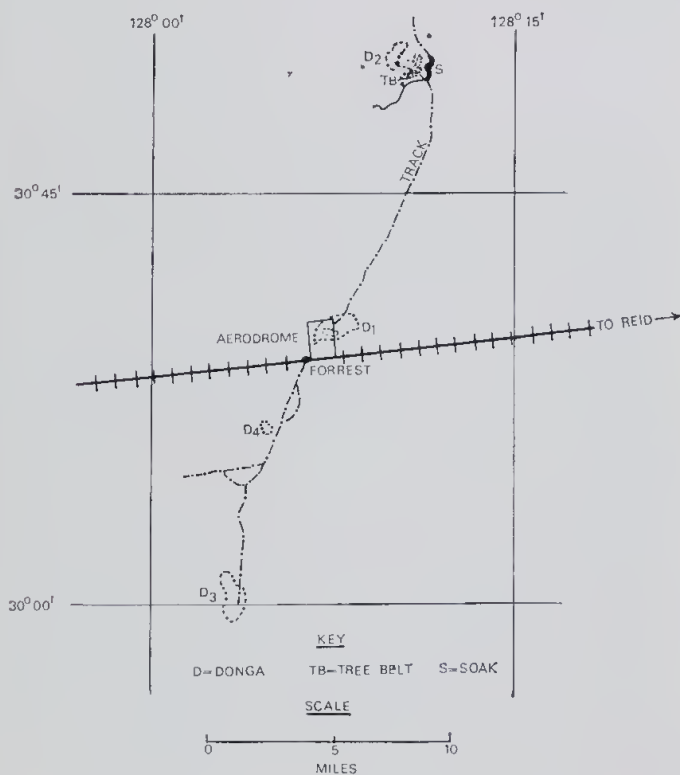


Figure 1.—Map showing the location of the Nullarbor Plain, Forrest and some other stations along the transcontinental railway.



### Rainfall

Annual rainfall for the 30 years between 1925 and 1955 (fig. 3) demonstrates the great variability; totals in this period ranging from 2 to 16½ inches. The published average for 50 years to 1965 is 6.5 inches. The average monthly rainfall is almost the same for each month of the year (fig. 4) but this indicates only that rain may fall in any month; the actual falls in any one year are very unevenly distributed.

The seasonal distribution and the way in which the rain falls is important to the vegetation not only for germination and maintenance of growth but also in the location of available moisture. Heavy downpours on dry ground mean run off and accumulation at lower levels; dongas may become lakes. After 6 inches of rain in February, 1930, a lake 3 miles across formed 13 miles west of Forrest and persisted for several weeks. Repeated light falls with little or no run off are of greater benefit to the higher levels of the Plain with its bluebush community. In general, summer rains tend

Figure 2.—Sketch showing tracks running N and S and approximate position of localities visited in relation to the railway line and aerodrome.



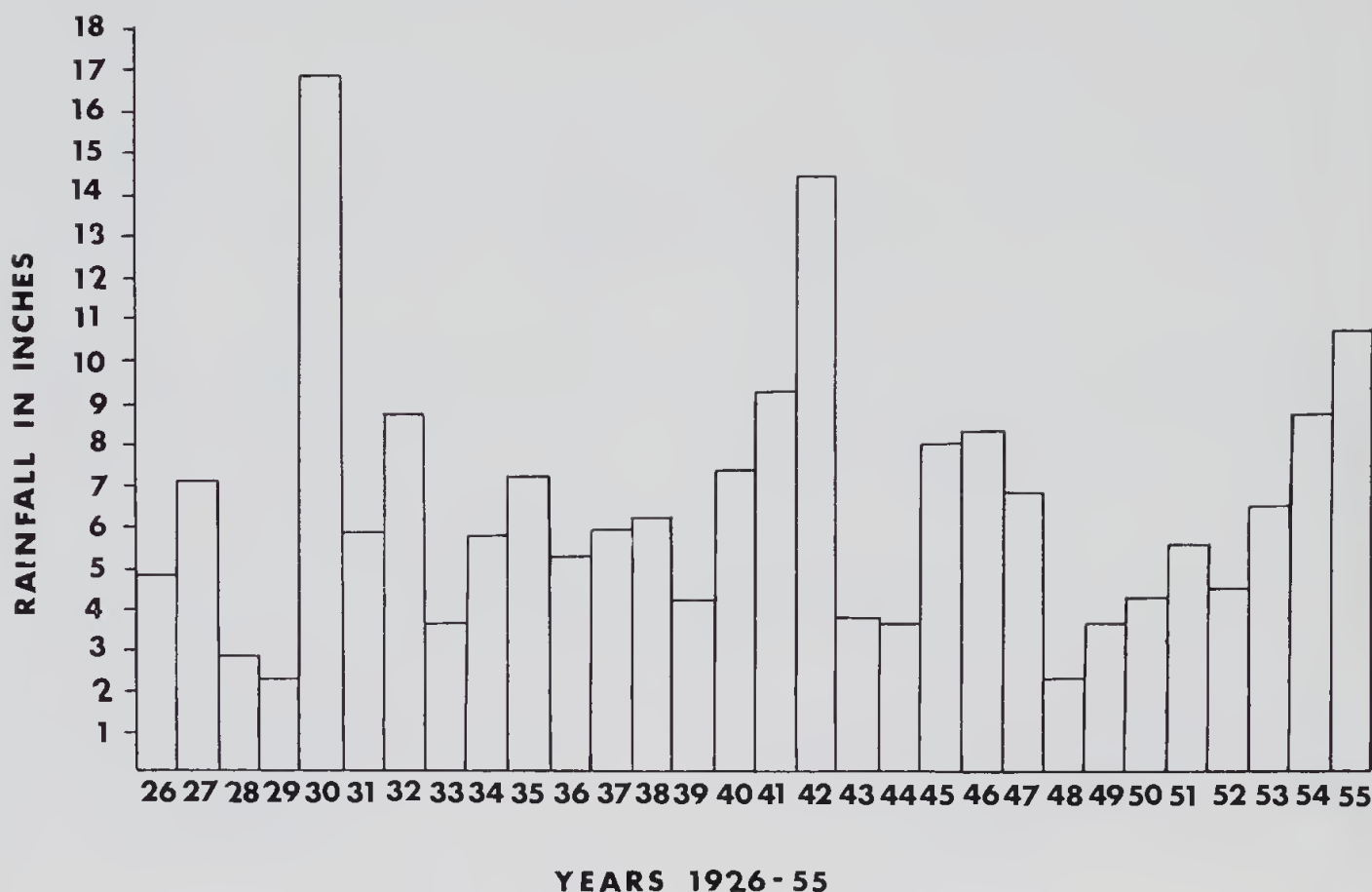


Figure 3.—Annual rainfall at Forrest for a 30 year period.

to come in heavy downpours, often causing flooding, while winter rains are usually lighter, more frequent falls.

For the years in which collections were made, 1955 can be seen as the second year of above average rain after a period of drought and 1930 as a quite exceptional high after a long and extreme drought.

#### Vegetation

**Plain.** The higher levels of the Plain carry the characteristic shrub steppe with the bluebush *Kochia sedifolia* as the dominant and almost the only perennial. The condition of the bluebush varied in different areas and over much of the Plain all that remained were long persistent dead stems. One such area (fig. 6A) was examined about 1-2 miles to the N.E. of the airport beyond a big donga. The plain here appeared to be the same in all directions as far as the eye could see except towards the donga. The soil was shallow reddish loam over travertine limestone which outcropped and lay in broken fragments on the ground. Lichens encrusted the rock (fig. 5 & fig. 6A) and also occurred on some of the bare ground. No living bluebushes were found; the dead bushes, as by notebook in figure 6A, showed the pattern of the original bluebush steppe. There was a marked tendency for concentration of annuals against these old plants. The ground cover was relatively sparse with bassias particularly *Bassia patentiuspis* and *B. uniflora* predominating (fig. 6A). Several different periods of origin were indicated by their differences in size

which ranged from relatively woody small bushes to single stemmed seedlings. Two small composites *Angianthus brachypappus* and *Gnephosis skirrophora* also contributed to the ground cover.

Other areas of high plain were seen on the trips to the north and south. To the north there were two areas where the bluebushes had compact foliage and few projecting dead stems (fig. 6B). *Angianthus* in full bloom formed a conspicuous ground cover. The track going for 12 miles south of the line crossed areas in which there were very open stands of bluebush intermixed with sparse tufts of *Stipa nitida*. Again *Bassia* spp and *Angianthus* were the main components of the sparse ground cover. Similar mixed stands of *Kochia* and *Stipa* were also seen beyond the 12 mile donga.

**The dongas.** Shrubs or small trees show from a distance the presence of a donga. In this flatness anything more than 3 feet high is conspicuous on the skyline. Vegetation of the dongas varies with size, depth and depth of soil but species of *Acacia*, *Eremophila* and *Pittosporum phylliraeoides* are the usual tall shrubs with patches of perennial chenopods other than *Kochia sedifolia* and, after rain, a lush herbaceous growth.

Three big dongas were examined. The first (D, on species list) at the N.E. corner of the aerodrome was more thoroughly examined than other dongas. A line was taken from the high plain on the N.E. towards the hangar and a series of photographs taken and specimens col-

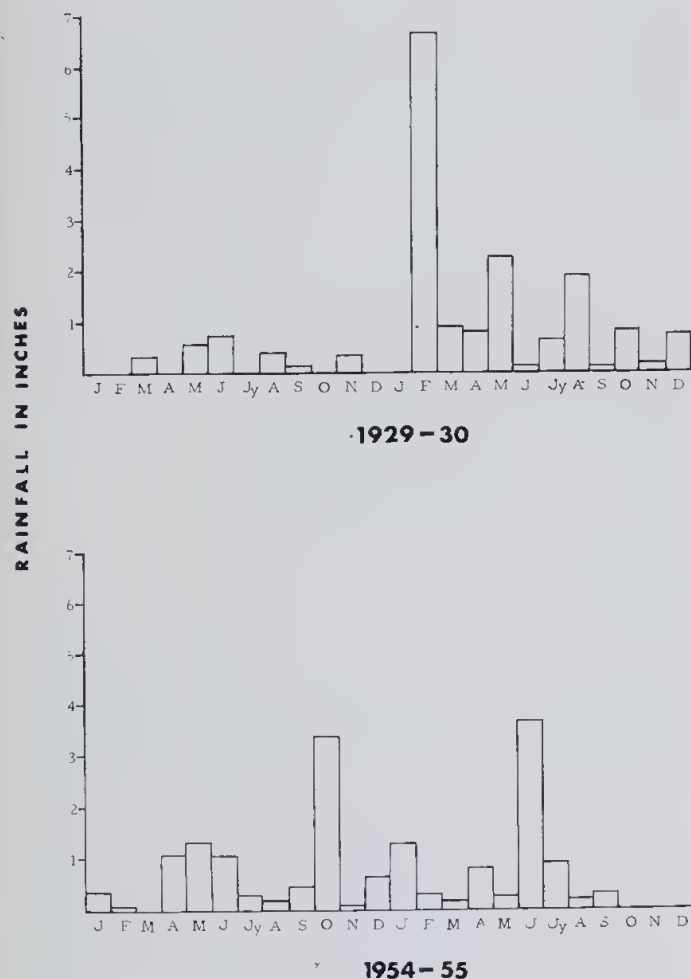
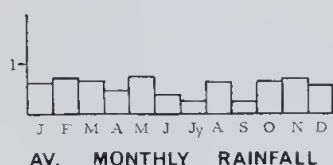


Figure 4.—Monthly rainfall for the years 1929-30 and 1954-55 and the average monthly rainfall.

lected along the transect with side detours where variations were noticed. A long, very gradual slope with sparse vegetation and much bare ground led down from the plain of Figure 6A already described. *Bassia* spp and *Salsola kali*, patchily distributed, were the main plants. Old rabbit burrows were numerous. Spreading from the mouths of some of these were big patches of *Tetragonia eremaea* showing vivid green in contrast to the prevailing grey of the bassias. Further down the slope dried and cracked mud showed where water had been lying. An adjacent low level area had a relatively rich cover of bushes up to 2 feet high of the perennial *Atriplex cryptocarpa* with some plants of *Lavatera*, *Nicotiana* and *Lycium*. Herbaceous dicotyledons: the slender straggly climber *Convolvulus erubescens*, the legume *Psoralea cinerea* and some composites and crucifers were scattered but principally in the shelter of the perennials throughout the lower levels of the donga.

The central area (fig. 7A) was grass-covered with several big spreading clumps of *Eremophila longifolia* and a few small *Pittosporum*. The grass cover was of the tufted grasses *Stipa nitida*, *Stipa* sp. and *Danthonia caespitosa*. Towards the periphery of the grass and beyond were a number of *Acacia oswaldii* bushes. Wherever seen these had a broad squat compact silhouette easily distinguishable at a distance. Many of them were heavily infested with the mistletoe *Amyema praeisii*; all showed rabbit pruning. Several had old bushes of *Atriplex rhagodioides* growing up in their shelter (fig. 7B). No isolated plants of the *Atriplex* occurred, presumably because only within the protection of the *Acacia* could they escape destruction by rabbits.

At 12 miles south of the rail a big donga ( $D_3$ ) had a rather richer vegetation. *Grevillea nematophylla*, not found in  $D_1$ , occurred both as trees and shrubby re-growth. *Acacia oswaldii* was in much more vigorous condition than in the airport donga and seemed free of mistletoe. There were a few small shrubs of *Eremophila maculata* as well as the taller *E. longifolia*. *Enchylaena tomentosa* was growing in the shelter of a *Pittosporum* and *Grevillea* and there were extensive colonies of *Atriplex cryptocarpa*. The herbaceous cover was of the same species as in the first donga but more luxuriant, the ground was moist to the touch and moss occurred under some of the bushes. A few plants of *Chianthus formosus* (Sturt Pea) were found here. A small donga 4 miles south of the railway had many rabbit burrows. *Zygophyllum* spp were relatively abundant on the bare mud with dwarf composites and there was a dense colony of *Atriplex cryptocarpa*.

About 15 miles to the north of Forrest and adjacent to the 14 mile tree belt another big donga ( $D_2$ ) was visited briefly and some koda-chromes taken and specimens collected. Large shrubs present were as in other dongas; *Acacia oswaldii*, *A. tetragonophylla*, *Eremophila longifolia*, *Pittosporum phylliraeoides*, and a few old trees of *Grevillea nematophylla*, one with an eagle's nest. Near the centre of the donga a big spreading clump of *Grevillea* (Fig. 7D) with abundant new growth and silvery dissected leaves contrasted with the heavy dark brownish leaves of *Acacia oswaldii* and the yellowish weeping foliage of the *Pittosporum*. In the shelter of this and other big shrubs were dense growths of trailing herbaceous species as listed for other dongas. Most of the herbaceous species were well past their maximum flowering and in fruit but with enough flowers left on some plants to enable identification. Bassias were present more or less throughout the donga. Large flat areas were grass-covered with the previously found species of *Stipa* and *Danthonia*, also *Eragrostis dielsii* var *pritzelii* in a big patch covering a depression within the donga.

Apart from the dongas with trees and shrubs there are extensive flat areas at slightly lower level than the high plain and where the soil is deeper without the exposed travertine. These are more or less bare in dry years but carry a luxuriant cover of grasses after heavy rains. One such stretch, shown in colour plate (fig. 9A) was crossed about 7 miles north of the air-



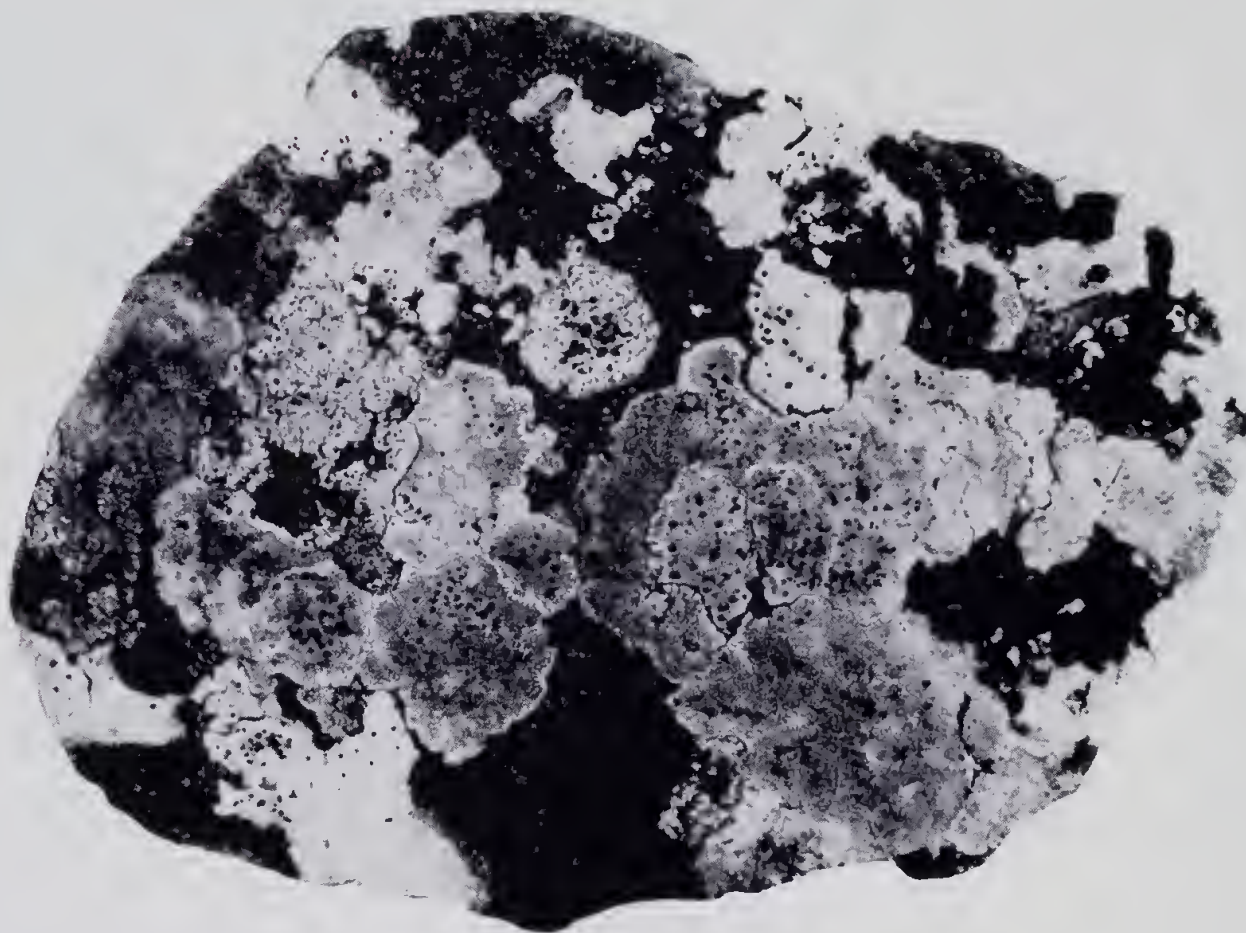


Figure 5.—A piece of flat lichen-encrusted limestone from the surface of the plain. The conspicuous species is *Buellia subalbula*.

port, extending continuously for about  $1\frac{1}{2}$  miles with further broken patches. This grass community was made up of the same two species of *Stipa* and one *Danthonia* as found in the dongas. No detailed examination of the area was made.

Although the three grasses were found together in most of the grassed areas, there was a difference in their distribution. *Stipa nitida* appeared to be the most xerophytic as it was the only species where grass occurred as sparse tufts (fig. 6D) on the higher levels (fig. 7A). The unidentified *Stipa* with golden brown fruits, *Stipa* sp aff *fusca* was abundant in the deeper part of the dongas. The best growth of *Danthonia* was seen also at the lower levels and in the more favourable habitats near airport and line. An observation of interest was the seeds of *Stipa* and *Danthonia* lined up in the pattern of cracked dried mud where water had lain. The long hygroscopically twisting awns are particularly suited to driving the seeds, radicle end down, firmly into the cracks.

**Minor depressions.** A variety of smaller irregularities and depressions, into which water may drain and soil is deeper, form locally favourable habitats. Figure 7D, a photograph of broken ground about 5 miles west of Forrest, shows the greater size and abundance of plants in small depressions. One depression seen just south of the railway had a stand of *Atriplex hymenocarpa* in flower. Four species of *Bassia* were also collected here. Slightly further east, on this rather stony irregular south side, other

depressions with annual saltbushes were found and two plants of *Kochia georgei*.

A stand of *Heterodendrum oleaefolium* had been found in this area in 1930, the trees heavily infested with mistletoe and mostly in poor condition. In 1955 all except one were dead, two fallen and a few standing. There had been no regeneration.

**Tree belt.** About 14 miles north of the airport and covering 20-30 acres, is a belt of Myall (*Acacia sowdenii*), spreading trees 10-15 feet high. In 1955 the majority of these were dead or almost so (fig. 8A). This tree belt had been visited in 1930 when most trees were alive and looking healthy (fig. 8B) even though they had just recovered from a particularly severe drought. No young trees were seen in either year. One old semi-fallen tree, which had been photographed in 1930, was found again still alive and not very different 25 years later. Several eagles' nests were present both in 1930 and 1955. *Exocarpos aphyllus* found in 1930 was not seen in 1955. A few perennial saltbushes were growing close to trees. The ground cover was low and fairly sparse but with a variety of annual species (figs. 8A & C). *Helipterum floribundum*, in full bloom, was conspicuous and extended well beyond the limits of the trees but the plants were mostly only a few inches tall. *Cephalopterum drummondii* was present in smaller numbers. Other small composites were *Podolepis canescens*, *Helipterum tietkensii* and *H. tenellum*. *Zygophyllum iodocarpum* and *Z. ovatum* were



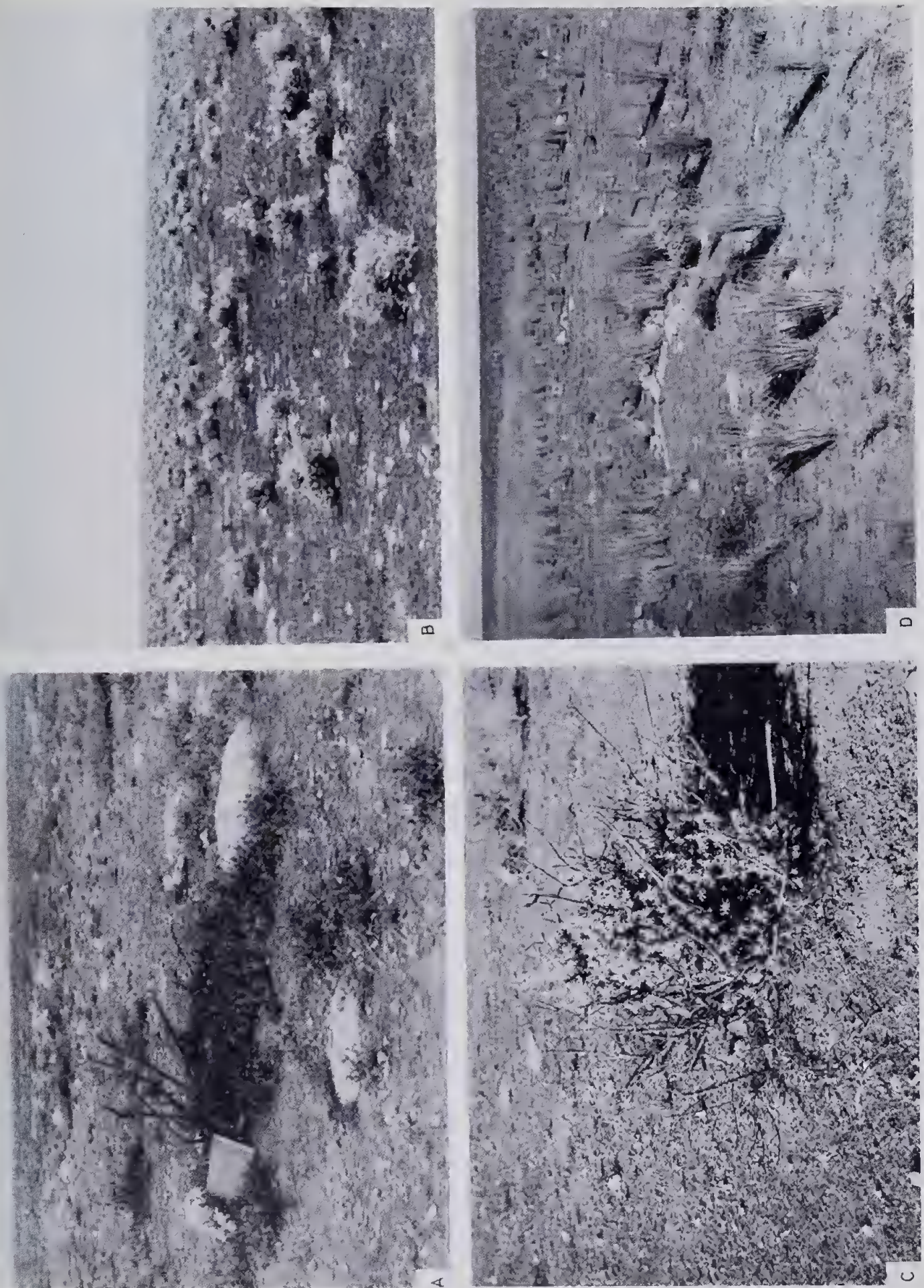


Figure 6.—A. A part of the plain to the east of donga 1 showing outcropping and fragmented limestone at the surface; absence of living bluebush and sparse cover of Bassias etc. B. Another part of the plain to the north where bluebush (*Kochia sedifolia*) was in healthy condition. C. A single plant showing partial recovery after drought. D. *Stipa nitida* in a slightly depressed area. The tufted habit is well shown in the foreground plants.



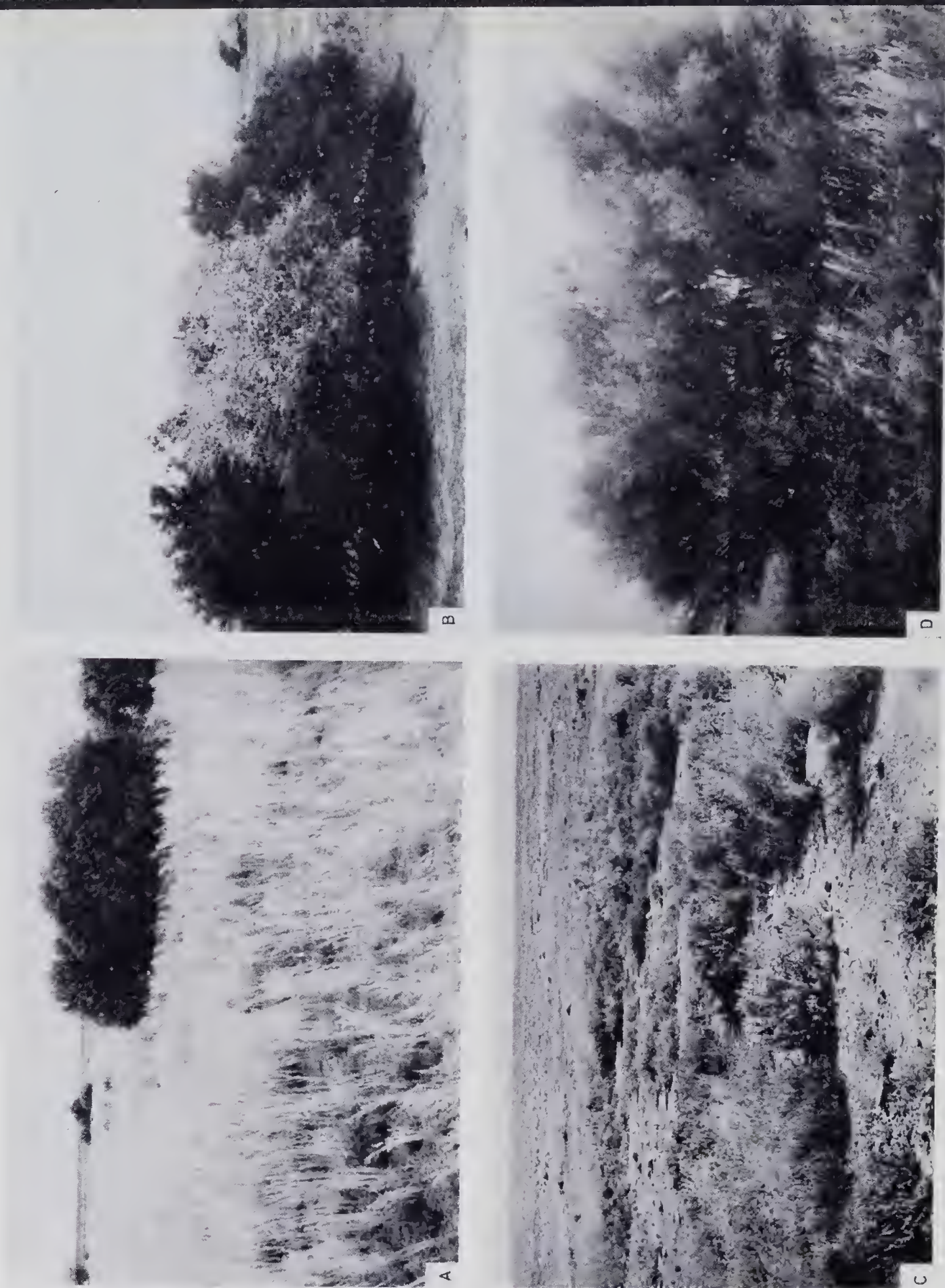


Figure 7.—The dongas. A. The grass covered area of donga D<sub>1</sub> with *Eremophila longifolia* (2 clumps) and a *Pittosporum phylliraeoides* in left distance. B. *Acacia oswaldii* with *Atriplex rhagodioides* both pruned by rabbits. C. More luxuriant growth in minor depressions—broken ground five miles west of Forrest. *Atriplex hymenotheca*, centre, *Atriplex cryptocarpa* grasses and other plants. Typical stony plain in the background. D. A clump of *Grevillea nematophylla* in the northern donga D<sub>2</sub>.



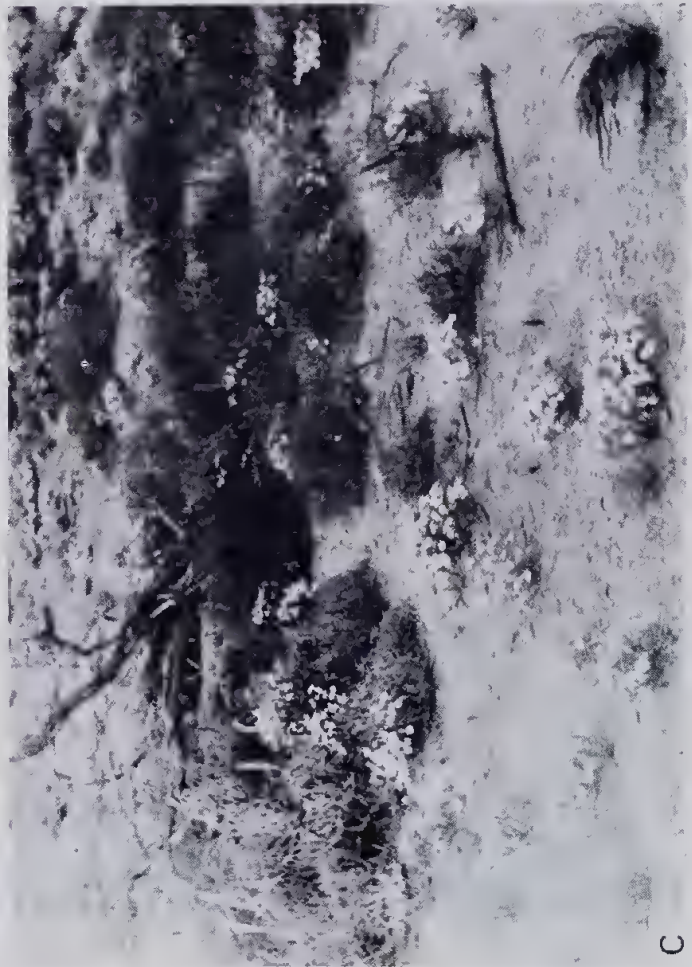


Figure 8.—Tree belt and soak. A. General view of part of the 14 mile tree belt in 1955 showing most of the trees dead. B. View in 1930 shows the habit of the living Myall (*Acacia sowdenii*) and some dead trees. C. Detail of undergrowth in 1955, *Helipterum floribundum*, *Zygonhyllum* spp, grass. D. View of part of the soak in 1930; lush growth of *Helipterum tietkensii* in foreground, *Lavatera* etc. behind and the trees on right skyline.



abundant forming almost pure stands in places. *Salsola kali* was also abundant, as were the almost universal bassias, with scattered small tufts of *Stipa nitida*. A few small plants of *Nicotiana goodspeedii* were found. Concentration of plants against fallen logs and dead plants, and in slight depressions was very noticeable.

**Tree belt soak.** A particularly interesting area locally known as "the 14 mile soak" led into the tree belt, possibly marking an underground, or sunken, drainage system. A distinct edge was marked by a line of bushes—*Kochia*, *Lycium*, *Lavatera*—with, to the lower side, a lush growth, up to 24" tall (Colour plate fig. 9B) of the grass *Eragrostis setifolia*, and of *Helipterum tietkensii*—a tall slender scented composite with abundant small silky heads. Further over was an area of bare and broken ground with old rabbit burrows, part stony, part rather "fluffy" soil, all extensively disturbed by rabbits and with a very patchy cover of the above mentioned grass and composite, sometimes mixed, more often in pure stands. Colour plate (fig. 9B) shows part of this soak.

Figure 8B of the area in 1930 shows the richness of the growth that year. Also in 1930 in a section of the depression further north was a luxuriant growth of *Trigonella suavisima*, which had not been seen anywhere else. This species was not found in 1955 but it is probable that that particular section of the depression was not reached.

The plain outside the depression was the most barren seen anywhere, no living bluebush or salt bush and practically no herbaceous plants—mostly bare eroded soil between old dead stumps—no doubt denuded by the rabbits which inhabited the "soak".

**Disturbed areas.** In the neighbourhood of the airport, near the station and along the railway line inevitably the ground has been considerably disturbed, and some of this disturbance provides habitats more favourable than on most of the Plain. Loosened soil, depressions, drainage channels and, in places, additional water and nitrogen benefit both introduced and native species. For instance a drain along the airport fence had a lush growth of *Danthonia*, *Atriplex hymenotheca*, *A. spongiosa*, *Salsola*, *Senecio* and other indigenous composites, the introduced *Sonchus* and several species of introduced crucifers. On disturbed muddy areas where water had collected three species of *Bassia*, *Atriplex spongiosa*, *A. hymenotheca*, two species of *Zygophyllum*, *Helipterum floribundum* and *Senecio lautus* were common and in general more robust than in undisturbed areas.

Introduced weeds were found only in the neighbourhood of line and airport. Some of these may have become naturalised but others are probably only of sporadic occurrence from seed dropped from trains, dependent on finding temporarily favourable niches and not long persistent. The difference in lists of introduced species from the two visits is in keeping with this suggestion. The native plants found on the two visits were essentially the same.

## Comparison between 1955 and 1930

Rainfall in each of these years was abnormally high but the amount and distribution was very different as can be seen in Figure 3. 1955 was the second wet season after several dry years and the rain had been fairly evenly distributed with the heaviest falls in October, 1954, and June, 1955. 1930 had the highest total rainfall ever recorded at Forrest and over six inches, equal to the average annual total, fell in four days at the end of February. This occurred after the most severe drought recorded. Some of the differences in plant growth were undoubtedly related to these climatic differences. As seen in August, 1930, only six months after flooding rains, the perennials, *Eremophila* spp., *Acacia* spp., *Kochia sedifolia* and perennial species of *Atriplex* mostly had tufts of new foliage on old defoliated stems, many plants had not survived the drought. In October, 1955, most surviving perennials had abundant healthy foliage as the result of two successive favourable years.

On the other hand, the herbaceous vegetation was not nearly as dense and luxuriant in 1955 as it had been in 1930. This was particularly noticeable with *Helipterum floribundum* which had in 1930 formed complete cover in places and where the individual plants had been much taller. There is no doubt that the ground cover as a whole had been denser and the plants taller in 1930 but as the rainfall for the first half of the year had been almost twice as much this is no basis for suspecting any long term change in the herbaceous vegetation. It is interesting that the same herbaceous species were collected at each visit and had flowered about the same time in spite of the differences in total amount and distribution of the rain.

For the perennial cover both authors were satisfied that there had been a real deterioration. In the Myall belt most of the trees had died. Figures 8A and B show the difference although not taken from the same spot. Other 1955 photographs, too poor for publication, do include a tree recognisable as one photographed in 1930. No young trees had been seen in either year so it seems unlikely that the stand will recover. Regeneration from seed could have been expected in 1930 (16") and 1942 (14"). It seems likely that it was prevented by rabbits and that they are also responsible for at least some of the deterioration of the *Atriplex* and *Kochia*. Rabbits spread over the plain after wet seasons and no doubt as drought develops and the annuals disappear the grazing pressure on the perennials must be intense, before the unfortunate animals succumb. The absence of living bluebush near the railway line and on the plain near the "soak", both areas with numerous rabbit burrows, would support this.

With a perennial vegetation in precarious equilibrium with its environment where establishment of seedlings is always difficult, rabbits can destroy the seedlings before they are old enough to tolerate any grazing and so effectively prevent regeneration.





Figure 9.—Top, Grass community 7-8 miles north of Forrest. *Bassia* spp. in foreground. Bottom, Soak—*Helipterum tietkensii* in the depression, a large *Kochia sedifolia* plant on the rim.





## Discussion

The plant communities seen at Forrest are typical of the central and western side of the Nullarbor Plain. The same bluebush association of the higher levels in many parts in very denuded condition, the flats with grass after rain, and the dongas of varying size can be seen from the train along the 165 miles between Forrest and Rawlinna.

The transition from the open dwarf shrubland of the Plain to the woodlands with Mallee Eucalypts, *Acacia* or *Casuarina* and an undergrowth of saltbush-bluebush or spinifex, occurs very gradually on the western side. The boundary of the Plain is usually put between Naretha and Rawlinna (fig. 1), but there is no clearly recognisable boundary for the vegetation; stands of shrubs and small trees become gradually more frequent from some miles east of Rawlinna, westward.

Although the Nullarbor Plain is distinctive in appearance and recognised as a geographical entity the vegetation consists of impoverished extensions of types found in slightly higher rainfall regions to the north east. The *Kochia-Atriplex* communities of northern South Australia and western New South Wales are described as having spaces between the bushes more or less equal to the diameter of the plants; on the Plain the spaces are vastly greater. The occasional belts of *Acacia sowdenii* could be considered outliers of the more extensive Myall formations outside the limits of the Plain and species of the dongas are mostly found in the surrounding shrub or woodland communities.

It seems probable that most of the perennial species are near the limit of their tolerance of low rainfall. The stress of the climate is shown in the number of plants dead after a prolonged drought and in the structure of the woody stems of shrubs. When plants recover after drought dead stems are left projecting, (fig. 6C) and the cambium has often been killed on one side of surviving stems resulting in uneven and deformed growth.

With an average annual rainfall of only 6½ inches the Nullarbor Plain could be classed as desert and as with most desert areas perennial species are few and annuals form the greater percentage of the flora. Nevertheless the concept of tiny ephemerals appearing, flowering, fruiting and dying in a few weeks as known for some deserts does not seem to apply here, except for very few species. The grasses, bassias and annual saltbushes and at least some of the herbaceous composites and legumes, which form the bulk of the herbaceous vegetation, may last for many months and even more than a year under favourable conditions. The annual everlastings *Helipterum floribundum* and *Cephalopterum drummondii* and also *Goodenia pinnatifida* showed evidence of extended growth and in the 1955 specimens, of two distinct periods of growth and flowering. Local comment in October was that these and some legumes had been flowering for many weeks and photographs taken in early December showed everlastings still in flower. *Stipa nitida* is known to behave as a perennial under favourable conditions though more often as an annual in the drier

parts of its range. Perhaps the ability to shorten or lengthen the life span is one of the effective adaptations to variable rainfall.

The Chenopodiaceae, particularly *Atriplex* spp. have been shown to be particularly well adapted to the absorption of moisture through the leaves and it is probable that dew plays an important part in extending the effectiveness of light falls of rain. Heavy dews and occasional fogs are known on the Plain and more knowledge of their contribution to the survival of grasses and other species would be valuable. The place of dew in the survival of rabbits is suggested by the observation by local residents of rabbits lined up along the train line in early morning licking the dew from the rails.

A three day visit to a region does not allow study of the ecology beyond recognition of species and types of communities, but it does suggest possibilities for investigations by someone living in the area. Within the dongas there is great variation in the shrubs and ground cover associated with minor differences in habitat. McCrumb (unpublished teachers thesis) at Reid made some useful observations on depths of soil associated with plant communities and on growth habits of certain species.

Some detailed observation on the percentage recovery of *Kochia* and *Atriplex* after drought and conditions necessary for their replacement by seedlings would be valuable. Is it true that there is at the present time a real deterioration of the bluebush and saltbush communities as the authors suggest, and, if so, how far are rabbits responsible? Some long term studies of regeneration of species of *Acacia*, *Atriplex* and *Kochia*, *Heterodendrum*, *Stipa* which extend across the Nullarbor have been made in South Australia, particularly at Koonamore (Hall et al 1964; earlier papers are listed in this), but in regions much further east and in rather different habitats. There is need for ecological studies on the western side of the Plain.

## Flora

**Systematic representation.** The number of Angiosperm taxa collected was 105 and their totals and relative numbers are given in Table I. Indigenous plants comprised the majority of the 27 families present. Among these 4 were prominent in both numbers of species and individuals. The Poaceae (7 sp. and 1 ssp.), Asteraceae (14 sp.), Chenopodiaceae (19 sp.) and Fabaceae (7 sp. and 1 ssp.) together contained half the genera and over half the species. The remaining 19 families were each represented by only 1 to 4 species. The vegetation was composed principally of large numbers of chenopods and grasses, with composites conspicuous in smaller areas. Legumes were

TABLE I.

	Families	Genera	Species	Sub-species	Varieties
Total	27	67	98	3	4
Indigenous	24	48	78	3	2
Introduced	9	20	20	0	2



usually found in the moister parts of the dongas, where *Lotus cruentus* and *Swainsona campestris* were locally massed. *Trigonella suavissima* formed an extensive and dense colony in one part of the soak.

Introduced plants were mostly few in number and not prominent among the luxuriant growth of saltbushes and grasses. Exceptions were tall robust plants of the Brassicaceae, a single flowering colony of *Asphodelus fistulosus*, large plants of the two varieties of *Medicago polymorpha* and the grasses *Lophochloa pumila* and *Schismus barbatus*. Only 4 of the 9 families were represented by more than one species. These were Poaceae (6 sp.), Brassicaceae (5 sp.), Boraginaceae (2 sp.) and Asteraceae (3 sp.).

Of the lower plants, 12 lichens and 1 moss (sterile and not identified) were found. No ferns were seen.

**Geographical distribution.** The range of a number of indigenous species cannot be determined until more field studies are made on the Plain and its surrounding areas.

On present evidence the Plain is the centre of distribution for only 3 species—*Atriplex cryptocarpa*, *Swainsona campestris* and *Calotis breviradiata*. Most of the others have a wide distribution, 67 out of 76 occurring both on its western and eastern sides throughout the more arid parts of Western Australia and South Australia. Some of them, such as *Pittosporum phylliraeoides*, *Salsola kali*, *Enchylaena tomentosa* and *Senecio lautus* are found in both coastal and Ereman areas.

To the east, 56 extend into western New South Wales and 48 are recorded from Central Australia. A few species have a still wider range and are found in the higher rainfall areas of south-western and south-eastern Australia. These are *Danthonia caespitosa*, *Oxalis corniculata*, *Euphorbia drummondii*, *Lavatera plebeia*, *Convolvulus erubescens*, *Plantago varia* and *Vittadinia triloba*.

The distribution of *Bassia parallelicuspis* and *Erodium cygnorum* ssp. *glandulosum* is considered to be eastern, while that of *Erodium cygnorum* ssp. *cygnorum* is mainly western, though it has been recorded from northern South Australia (Carolin 1958).

The present known range of *Eragrostis dielsii* var. *pritzelii*, *Grevillea nematophylla* an undescribed var. and *Atriplex hymenotheca* is western. All three have been recorded from widely separated localities, so their range may be found to extend further east when more information is available.

All the introduced species had previously been recorded for Western Australia and South Australia. Twelve were collected in 1930 and fifteen in 1955. Ten of the latter were new records for Forrest (see in Annotated List).

*Hordeum leporinum*, *Lophochloa pumila*, *Schismus barbatus*, *Chenopodium murale*, *Papaver hybridum*, *Brassica* sp. and *Medicago polymorpha* var. *brevispina*, collected in 1930, were not found in 1955.

## Annotated List of Species from Forrest

Specimens, after detailed examination, were compared with those available in the Tate Herbarium, Adelaide, the State Herbarium of South Australia, the Western Australian Herbarium, and a few in the National Herbarium of Victoria. Several specimens were not determined. For some others, where resemblances to particular species were found to be close, differences have been noted and the species determinations given are regarded as tentative. Nomenclature followed is that in Black's Flora of South Australia (2nd ed. 1943-1957) and its Supplement (Eichler, 1965). Collections are in the herbarium of the Botany Department, University of Western Australia (U.W.A.), and a duplicate set has been sent to the C.S.I.R.O. Herbarium, Canberra.

Localities are shown as under. Distances are approximate from the Forrest railway station.

P—plain

TB—tree belt, N 14 miles

S—soak, N 14 miles

R—disturbed soil near railway line and airport

D—dongas

D<sub>1</sub>—NE 1 mile

D<sub>2</sub>—N 15 miles

D<sub>3</sub>—S 12 miles

D<sub>4</sub>—S 5 miles

The months August and October refer to plants collected in August 1930 and October 1955 respectively. A species was abundant and in flower and fruit unless otherwise stated. An asterisk denotes an introduced species.

## ANGIOSPERMAE POACEAE ( GRAMINEAE)

\**Avena fatua* L. (R)—in fruit (Oct.).

\**Bromus unioloides* H.B.K. (R)—near septic tank overflow, rare (Oct.).

*Danthonia caespitosa* Gaudich. (P D<sub>1</sub> D<sub>2</sub> S R)—often mixed with *Stipa*; variable in height  $\pm$  30 cm. in moist places, small scattered tufts  $\pm$  10 cm. on bare areas. (Aug. Oct.)

*Eragrostis scitifolia* Nees (S)—mixed with *Helipteryx tielkensis* to form a dense mass;  $\pm$  30 cm. tall; smaller and less numerous in 1955 (Aug. Oct.).

*Eragrostis dielsii* Pilger (P S R)—small erect tufts in damp depressions (Aug. Oct.).

*Eragrostis dielsii* var. *pritzelii* Pilger (P D<sub>2</sub> R)—mat plant, on bare clay around aerodrome and on surface of donga among erect plants of a fairly dense ground flora. (Aug. Oct.)

This variety described by Pilger (1904) has since been recorded from some widely separated localities in Western Australia (Gardner 1952). The habit of the Forrest specimens was compact with numerous horizontally spreading culms without erect ones and they appeared distinct from the erect tufted plants of

*E. dielsii* which occurred near them by the aerodrome. Both erect and mat plants matched those of *E. dielsii* and its var. *pritzelii* in the W.A. Herbarium.

\**Hordeum leporinum* Link (R)—rare (Aug.).

\**Lolium perenne* L. (R)—rare (Oct.).

\**Lophochloa pumila* (Desf.) Bor. (R)—(Aug.).

\**Schismus barbatus* (L.) Thell. (R)—frequent; prostrate in the open, upright in shelter,  $\pm 30$  cm. tall (Aug.).

*Stipa nitida* Summerh. et Hubbard (P D<sub>1</sub> D<sub>2</sub> D<sub>3</sub> T B R)—Colonies prominent and extensive; plants 10-90 cm. tall, the larger in damp depressions and dongas, the smaller mostly with colonizers of bare areas (Aug. Oct.). There is no published record of this species for Western Australia. However eight specimens collected from the following localities in the Ereman Province since 1947 are in the W.A. Herbarium.<sup>1</sup> Kalgoorlie, S. T. Blake; Berringarra, N. H. Speck; on Barwidgee Road, N. H. Speck; Agnew, T. E. H. Aplin; N. of Sandstone, Cundeelee Mission, E. of Cosmo Newbery, A. S. George; near Haig, D. W. Goodall.

*Stipa eremophila* Reader (P D<sub>2</sub> D<sub>3</sub> TB R)—scattered or in small groups; most abundant near aerodrome and railway (Aug. Oct.).

*Stipa* sp. (R) (No. 68, 1930)—rare, in shallow soil; grey colour; sheaths and leaves very villous; 20-40 cm. tall (Aug.). The colour of this grass gave it a distinctive appearance. It had long glumes ( $\pm 18$  mm) with acute hyaline tips, long awns (6-7 cm.) and smooth dark brown lemmas with dense golden to dark brown silky hairs on their calli.

*Stipa* sp. (R) (No. 65a, 1955)—rather rare, in depressions; panicle narrow; fruits small, brown with fine awns, lemmas with whitish hairs (Oct.).

*Stipa* sp (D<sub>1</sub> D, R) Nos 17, 65b, 1955)—abundant in centre of dongas and near railway; 60-90 cm tall; fruits large, dark brown, lemmas hirsute (Oct.).

The last three specimens need further study.

*Stipa* species were found in all dongas examined and were predominant over most of the slightly lower areas of the plain.

#### LILIACEAE

\**Asphodelus fistulosus* L. (R)—only a single colony (Aug.); scattered over a wider area; plants to 40 cm tall; most in fruit (Oct.).

#### PROTEACEAE

*Grevillea nematophylla* F. Muell. var. (D<sub>2</sub>D<sub>3</sub>)—shrubs, isolated or in groups; 2.5-4 m; foliage dense, silvery, leaves more or less erect, 6-18 cm long, divided into 3-7 terete, faintly grooved segments, 3-10 cm long, about 1 mm wide; racemes terminal, very young, 2 rudimentary flowers in axil of each bract; mature fruit similar to that of *G. nematophylla* (Oct.).

Differs from *G. nematophylla* in its divided leaves and the more erect position of its flowering axes which may be due to the immaturity of the inflorescence. Specimens with similar foliage are in the Tate Herbarium, Adelaide,

and the National Herbarium of Victoria. The Tate specimen, named *nematophylla*, was collected by Helms in December 1891 near Mt Churchman in W.A. The Victorian one, unnamed, was collected by Isaac Tyson in 1893 near the Middle Murchison River (W.A.) and sent to von Mueller.

#### SANTALACEAE

*Exocarpos aphyllus* R. Br. (TB)—3 small trees growing close to *Acacia sowdenii*;  $\pm 2$  m; in flower (Aug.).

#### LORANTHACEAE

*Amyema preissii* (Mig.) Tiegh. (D<sub>1</sub>)—abundant on *Acacia oswaldii*; foliage bright green; in flower, fruits very young (Oct.).

*Lysiana exocarpi* (Behr) Tiegh. (P)—on *Heterodendrum oleaefolium*; fruit red, 8 mm long, ovoid (Aug.). Two forms were present on same host,

- (1) leaves mostly opposite, narrow linear, thick, flat, sub-acute or obtuse, 3.5-4.5 cm long, 3-4 mm broad, venation obscure;
- (2) leaves all opposite, thin, long; narrow, 2 mm broad. In leaf and fruit characters both forms are similar to those of subspecies of *exocarpi* described by Barlow (1963). These could not be determined as no flowers were found.

#### POLYGONACEAE

\**Emex australis* Steinh. (R)—in fruit (Aug. Oct.).

#### CHENOPODIACEAE

*Atriplex acutibractea* Anderson (P R)—in damp depressions; erect, stiff, branched,  $\pm 25$  cm tall (Aug. Oct.).

*Atriplex cryptocarpa* Aellen (D<sub>1</sub> D<sub>3</sub> D<sub>4</sub>)—shrub to 70-80 cm tall; in flower, heads small, axillary (Oct.). Dominant shrub in D<sub>3</sub>, a small colony on one side of D<sub>1</sub>.

*Atriplex eichleri* Aellen (R)—perennial on damp clay; branches lax, more or less prostrate, 15-40 cm long (Aug.). A new species described by Aellen (Eichler 1965) who found the type specimen of *Atriplex campanulata* var. *adnata* belonged to it.

*Atriplex hymenotheca* Moq. (P D<sub>1</sub> R)—perennial in damp depressions; profusely branched,  $\pm 40$  cm tall; leaves entire, a few toothed, to 2 cm long, obovate, scaly, subsessile; all plants examined except one dioecious; bracteoles rhomboid, entire, the bladder-like appendages variable in size, sometimes absent (Aug. Oct.).

This species is regarded as a western one and has been united with *A. vesicaria* (Howard) Benth. as *A. hymenotheca* Moq. by Aellen (1938). However *vesicaria* is retained as a separate species by workers in Eastern Australia.

*Atriplex rhagodioides* F. Muell. (D<sub>1</sub>)—shrubs to 1-1.5 m, growing in shelter of *Acacia oswaldii* (Oct.).

*Atriplex spongiosa* F. Muell (P R)—annual, erect to 30 cm, luxuriant growth where water had lodged, and small in shallow soil with less moisture (Aug. Oct.).

<sup>1</sup> Information from Mr R. D. Royce.



*Atriplex* sp. aff. *A. muelleri* Benth. (P)—erect, woody; old stems smooth; leaves 2-3.5 cm long, flat, toothed, mealy, narrowed into a petiole; only 2 very young flowers found, bracteoles united to just below the middle, entire,  $\pm$  rhomboidal; no fruits (Aug.).

*Atriplex* sp. (No. 17, 1930) (P R)—seedlings numerous, some old plants with regrowth from the woody bases; mature plants erect, stiff, to 30 cm; leaves 2-4 cm, obovate, apex pointed but some truncate, toothed, petiolate; monoecious; bracteoles united to near the middle, 3 or 5-toothed, the middle tooth deltoid, rather narrow, always longer than the lateral ones, the lower part of the bracteoles narrowed and hardened in the developing fruit into a small stipe-like base (Aug.).

The closest resemblance of these plants seems to be the South African species, *A. suberecta* Verdoorn.

*Atriplex* sp. (No. 83, 1930) (R)—prostrate, woody, stems  $\pm$  15 cm; leaves small, 5-9 mm long, obovate, green above mealy below; monoecious; axillary clusters of very young male and female flowers, bracteoles shortly stalked, 3-toothed, the middle tooth longer and deltoid; no fruits developed (Aug.). The flowers and bracteoles of this specimen are similar to those of the preceding ones but it differs in habit and foliage.

*Bassia obliquicuspis* Anderson (P D<sub>1</sub>)—on shallow limestone soil, also deeper soil in donga, with *Atriplex hymenotheca* and other *Bassia* spp.; plants small, compact, branching, 6-8 cm tall (Aug. Oct.).

*Bassia parallelicuspis* Anderson (P)—rare except in one small area south of the line; plants soft, erect, branching, 6-20 cm tall; tomentum brownish; flowers and young fruits (Aug.).

*Bassia patenticuspis* Anderson (P D<sub>1</sub> D<sub>2</sub> TB R)—colonizers; plants small, tomentum grey; fruits with 2 spines up to 6 mm long, acicular, glabrous except near base, some reddish distally (Aug. Oct.). Equal spines were rare and in a number of cases one spine was reduced to a tubercle. Variations in length occurred on a single plant. Ising (1964) says that more than half the specimens showing this type of variation in spine length have come from the Nullarbor Plain.

*Bassia sclerolaenoides* (F. Muell.) (P D<sub>1</sub> TB R)—rare in 1930, abundant and widespread in 1955; mainly on bare soil;  $\pm$  15 cm tall (Aug. Oct.).

*Bassia uniflora* (R Br.) F. Muell. (D<sub>1</sub> TB)—frequent (Oct.).

*Chenopodium cristatum* (F. Muell.) F. Muell. (R)—in wet places; mat plants, 10-50 cm diam.; some with regrowth from centre; fruits young and mature (Aug.).

\**Chenopodium murale* L. (R)—rare (Aug.).

*Enchylaena tomentosa* R. Br. (D<sub>3</sub>)—in shelter of *Pittosporum phylliraeoides*; fruits orange (Oct.).

*Kochia georgei* Diels (P R)—occasional; in fruit (Aug. Oct.).

*Kochia sedifolia* F. Muell. (P)—absent from dongas; many plants appeared dead, a few showed regrowth;  $\pm$  50 cm tall (Aug. Oct.).

*Salsola kali* L. (D<sub>1</sub> TB R)—colonizer; numerous seedlings, young and mature plants (Aug. Oct.).

#### AIZOACEAE

*Tetragonia eremaea* Ostf. (P D<sub>1</sub> TB R)—prostrate, plants large on bare soil near rabbit burrows, smaller in other places; stems to 25 cm long (Aug. Oct.).

#### PAPAVERACEAE

\**Papaver hybridum* L. (R)—rare; flowers and few fruits (Aug.).

#### BRASSICACEAE (= CRUCIFERAE)

*Arabidella trisecta* (F. Muell.) Schulz (P R)—scattered small shrubs;  $\pm$  40 cm tall; absent from dongas (Aug. Oct.).

\**Brassica* sp. aff. *B. tournefortii* Gouan. (R)—scattered, robust tall plants, to 60 cm; basal leaves, rosulate, large, 15-18 cm long including petioles, hispid, cauline leaves small, narrow-lanceolate, toothed; flowers pale yellow; fruits very young, 3-4 mm with beaks, cylindrical, single-veined (Aug.).

\**Carrichtera annua* (L.) DC (R)—in drainage channels; up to 40 cm tall; flowers white, in fruit (Oct.).

*Lepidium rotundum* (Desv.) DC (P D<sub>1</sub> R)—15-30 cm tall (Aug. Oct.).

*Phlegmatospermum cochlearinum* (F. Muell.) O. E. Schulz (D<sub>1</sub> R)—plants to 25 cm tall at lower levels of donga, smaller and less frequent on slopes; clothing hairs 2-branched on short stipes or centrifixed; flowers yellow; fruit  $\pm$  elliptical, style short (1 mm), cotyledons accumbent, some oblique, few incumbent (Aug. Oct.).

\**Rapistrum rugosum* (L.) All. (R)—plants to 40 cm; flowers yellow, fruiting (Oct.).

\**Sisymbrium irio* L. (R)—(Aug. Oct.).

\**Sisymbrium orientale* L. (R)—fruits immature (Aug.), few flowers, many fruits (Oct.).

#### PITTOSPORACEAE

*Pittosporum phylliraeoides* DC (P D<sub>1</sub> D<sub>2</sub> D<sub>3</sub>)—scattered small trees,  $\pm$  2 m tall; a few young plants; few flowers, fruits green or dehiscent (Aug. Oct.).

#### MIMOSACEAE

*Acacia oswaldii* F. Muell. (D<sub>1</sub> D<sub>2</sub> D<sub>3</sub> TB S)—shrubs, isolated or in groups in dongas or smaller depressions on plain; 2-3 m tall; dehiscent fruits and few buds (Aug.), buds, flowers and mature fruits (Oct.). In 1930 fruits (red) of one of the Loranthaceae were germinating on some of these shrubs and in 1955 those in a donga (D<sub>1</sub>) were heavily parasitized by *Amyema preissii*.

*Acacia sowdenii* Maiden (TB)—trees scattered over 20-30 acres; 5-6 m tall; flowers in globular heads (Aug.) Flowers and young fruits on some with sparse foliage, others appeared dead in 1955 (Oct.).

*Acacia tetragonophylla* F. Muell. (P D<sub>1</sub> D<sub>2</sub>) scattered shrubs; 1-2 m tall; flowers, no fruits (Aug.), few flowers numerous fruits (Oct.).

#### FABACEAE (= PAPILIONACEAE)

*Clanthus formosus* (G. Don) Ford et Vickery (D<sub>3</sub> S)—plants large, in flower (Aug.). Rare and small, only in one donga (Oct.).

*Lotus cruentus* Court (D<sub>1</sub> D<sub>2</sub>)—in shelter of other plants; stems long, trailing (Oct.).

\**Medicago polymorpha* var. *brevispina* (Benth.) Heyn (R)—occasional; plants large; spines on pod short (1 mm) both straight and hooked (Aug.).

\**Medicago polymorpha* var. *vulgaris* (Benth.) Shinnery (R)—occasional; spines on pod long (Oct.).

*Psoralea cinerea* Lindl. (D<sub>1</sub> S)—growing luxuriantly under other plants in centre of donga; stems prostrate, long (Oct.); abundant with *Trigonella suavissima*, flowers young, no fruits (Aug.).

*Swainsona campestris* J. M. Black (P D<sub>3</sub>)—in small damp depressions on plain, tends to be a scrambler in deeper soil of donga; flowering stems erect up to 40 cm, fruiting stems prostrate (Aug., Oct.).

*Swainsona oliveri* F. Muell. (R)—rather rare; colonizer; prostrate, stems to 15 cm; few buds, in fruit (Aug., Oct.).

*Swainsona oroboides* F. Muell. ex Benth. ssp. *oroboides* (P)—a single specimen in fruit (Oct.). The type of tomentum, leaf and fruit characters are similar to those described for this subspecies by Lee (1948).

*Trigonella suavissima* Lindl. (S)—native clover; plants up to 30 cm tall; formed a large dense mass in one part of the Soak (Aug.).

#### GERANIACEAE

*Erodium aureum* Carolin (TB R)—scattered in ground flora; plants small,  $\pm$  10 cm tall (Oct.).

*Erodium cygnorum* Nees ssp. *cygnorum* (P)—(Aug.).

*Erodium cygnorum* ssp. *glandulosum* Carolin (P R)—(Aug.).

These subspecies, which occurred together in shallow depressions, were readily separated on leaf form and type of calyx tomentum. Subsequent examination showed this was not so in respect to two other characters, the shape of the staminal filament and the mericarp hairs. In the specimen referred to ssp. *cygnorum* the staminal filament, instead of being lanceolate-acuminate as figured by Carolin (1958), had broad-oblong wings, slightly narrowed near the top with a tooth at each lateral edge of the upper margin. It was also different from Carolin's figure of the filament of ssp. *glandulosum*. In the specimen referred to ssp. *glandulosum* the mericarp hairs were more like those of ssp. *cygnorum*, but not quite as sparse or divergent.

Because of these variations the distinction between the subspecies was not clear, a condition Carolin said tended to occur when their ranges overlapped. This is so in the Forrest region as the range of ssp. *glandulosum* is mainly eastern and that of ssp. *cygnorum* mainly western.

#### OXALIDACEAE

*Oxalis corniculata* L. (R)—rather rare; small, prostrate (Oct.).

#### ZYGOPHYLLACEAE

*Zygophyllum iodocarpum* F. Muell. (TB R)—frequent; common in ground flora under *Acacia sowdenii*, also on bare areas of disturbed ground (Aug., Oct.).

*Zygophyllum ovatum* Ewart et White (P D<sub>3</sub> TB R)—common; small, to 10 cm tall, often prostrate (Aug., Oct.).

#### EUPHORBIACEAE

*Euphorbia drummondii* Boiss. (D<sub>3</sub> R)—rare; prostrate on bare clay (Oct.).

#### SAPINDACEAE

*Heterodendrum oleaeifolium* Desf. (P)—scattered small trees up to 2 m tall; foliage sparse; parasitized by a narrow leaved form of *Lysiana exocarpi*. (Aug. 1930). In 1955 (Oct.) most trees were dead.

#### MALVACEAE

*Lavatera plebeia* Sims (P D<sub>1</sub> TB S R)—frequent; scattered shrubs up to 1 m tall (Aug., Oct.).

*Sida cardiophylla* F. Muell. (R)—rare, small shrub, low spreading; in bud (Aug.).

#### CONVOLVULACEAE

*Convolvulus erubescens* Sims (P D<sub>1</sub> R)—occasional in depressions on plain, abundant at lower levels of donga; mat plants, large, stems slender, trailing and twining up to 60 cm long (Aug., Oct.).

*Convolvulus* sp. (D<sub>1</sub>)—a large bright green prostrate plant (Oct.). Differed from *C. erubescens* in its longer fruits and two sepals enlarged and spreading.

#### BORAGINACEAE

\**Buglossoides arvensis* (Patersons Curse) (L.) Johnston (R)—rare (Aug., Oct.). Some plants were erect, up to 30 cm tall, with flat sessile leaves, obtuse,  $\pm$  4 cm long by 6 mm wide. Others were more spreading, branching mainly near the base of the stem, with shorter, narrower, lanceolate or oblong leaves, 1.5 cm long by 2-3 mm wide.

\**Echium lycopsis* L. (R)—rare (Oct.).

*Omphalolappula concava* (F. Muell.) Brand (R)—rare (Aug.).

#### SOLANACEAE

*Lycium australe* F. Muell. (P D<sub>1</sub> S)—occasional; no flowers or fruits in 1930, both present in 1955.

*Nicotiana goodspeedii* Wheeler (D<sub>1</sub> TB R)—frequent; small in ground flora, 15-40 cm tall in centre of donga, glabrous; flowers cream to pale yellow (Oct.).

*Nicotiana suaveolens* Lehm. (R)—among weeds near a septic tank Overflow; a single robust, glabrous plant (Oct.).

*Nicotiana* sp. (possibly *N. benthamiana* Domin) (TB)—this specimen was lost after the following notes were made.



Plants numerous at the edge of a depression near *Acacia sowdenii*; up to 1 m tall, most about 50 cm; glabrous, basal leaves very large, cordate blades up to 20 cm long narrowing into long petioles, cauline leaves  $\pm$  10 cm not decurrent; flowers yellow, calyx lobes acute, divided nearly halfway to the base, hirsute, corolla tube  $\pm$  20 mm, 2-3 times as long as the calyx, lobes short, obtuse, stamens 5, 4 attached higher on the tube than the 5th; capsule smooth, as long as the calyx, seeds pitted (Aug.).

#### MYOPORACEAE

*Eremophila latrobei* F. Muell. (P)—scattered shrubs, to 1.25 m tall; few or no leaves on lower branches, new growth at upper ends (Aug.).

*Eremophila longifolia* (R. Br.) F. Muell. (P D<sub>1</sub>)—small trees up to 3 m tall; new growth at ends of branches (Aug. Oct.).

*Eremophila maculata* (Ker-Gawl.) F. Muell. (P D<sub>3</sub>)—small shrub in soil pockets in stony areas, occasional in a donga (Aug. Oct.).

#### PLANTAGINACEAE

*Plantago varia* R. Br. (R)—plants small, 10-14 cm tall (Aug.).

#### CUCURBITACEAE

*Cucumis* sp. (D<sub>1</sub>)—on bare clay; fruits only  $\pm$  2 cm in diameter; other parts of plants dead (Oct.).

#### GOODENIACEAE

*Goodenia pinnatifida* Schldl. (P D<sub>1</sub>D<sub>2</sub> R)—plants 15-40 cm tall, smaller ones on limestone among bluebushes, larger in deeper soil of dongas (Aug. Oct.).

#### ASTERACEAE (= COMPOSITAE)

*Angianthus brachypappus* F. Muell. (P D<sub>1</sub> R)—colonizers; mat plants to 30 cm in diameter (Aug. Oct.).

*Brachycome ciliaris* (Labill.) Less. var. *ciliaris* (TB)—scattered in ground flora under *Acacia sowdenii*; up to 25 cm tall, glabrous; leaves pinnatisect with 7 lobes; minute glandular pubescence on stems and leaves (Aug.).

*Calotis breviradiata* (Ising) G. L. Davis (D<sub>1</sub> D<sub>3</sub> R)—occasional; plants small up to 8 cm tall on the slopes of dongas, larger, 14-30 cm, in lower parts of dongas and drainage channels (Oct.). A species of the Nullarbor Plain (Davis 1952).

*Calotis hispidula* (F. Muell.) F. Muell. (R)—plants small 6-10 cm tall; leaves entire or toothed, sometimes both types on same plant (Aug.). Davis (loc. cit.) says that only entire-leaved forms have been seen from the Nullarbor Plain and Eucla areas.

\**Centaurea melitensis* L. (R)—occasional (Oct.).

*Cephalopterum drummondii* A. Gray (P D<sub>2</sub> D<sub>3</sub> TB R)—plants massed and prominent over large areas or scattered, 14-25 cm tall (Aug. Oct.).

*Gnephosis skirrophora* (Sond.) Benth. (P TB R)—on shallow limestone soil among bluebushes, frequent in other habitats; plants low tufted, 10-15 cm tall (Aug. Oct.).

*Helipterum floribundum* DC (P D<sub>1</sub> TB S R)—scattered in small depressions among bluebushes, large conspicuous colonies on slopes and lower levels of dongas; plants 5-30 cm tall (Aug. Oct.).

*Helipterum strictum* (Lindl.) Benth. (P)—occasional; plants erect, profusely branched, to 25 cm tall (Aug.).

*Helipterum tenellum* Turcz. (D<sub>3</sub> TB)—occasional, scattered in ground flora under *Acacia sowdenii* and on bare clay areas; plants small, tufted (Oct.).

*Helipterum tietkensii* F. Muell. (D<sub>3</sub> TB S R)—in soak forming a large dense colony, plants up to 35 cm tall (1930), in other habitats scattered and smaller  $\pm$  11 cm tall; heavily scented (Aug. Oct.).

*Minuria leptophylla* DC (P)—rare; plants small, freely branched, up to 15 cm tall (Aug.).

*Podolepis canescens* A. Cunn. ex DC (P TB R)—frequent on shallow soil, abundant on deeper soils; plants 12-30 cm tall (Aug. Oct.).

*Senecio* aff. *lautus* Forst. f. ex Willd. (P D<sub>1</sub>)—occasional in shallow depressions on plain, abundant in donga; plants 25-30 cm tall (Aug. Oct.).

\**Sonchus* sp. (R)—(Oct.).

*Vittadinia triloba* (Gaudich.) DC (P D<sub>1</sub> D<sub>2</sub>)—rare among bluebushes, frequent in dongas, plants to 15 cm tall (Aug. Oct.) most in fruit in 1955.

\**Xanthium spinosum* L. (R)—burr fruits near railway. (Oct.).

#### LICHENES

*Aspicilia calcarea* (L.) Mudd.

*Buellia subalbula* Nyl Müll. Arg.

*Dermatocarpon compactum* (Mess) Lettau.

*Lecanora sphaerospora* Müll. Arg.

These lichens were all found encrusting the surface of limestone fragments. *Buellia subalbula* (fig. 5) was the most abundant species.

*Lecidea decipiens* Arch.—encrusting soil.

*Lecidea crystallifera* Tayl.—sterile on soil.

*Lecidea* aff. *glauca* Tayl.—sterile on soil.

*Diploschistes* aff. *ocellatus* DC Norm.—sterile.

*Chondropsis semiviridis* Nyl (*Parmelia hypoxantha* Müll. Arg.)—loose on surface of ground under *Acacia sowdenii*.

*Teloschistes chrysophthalmus* (L.) Th. Fries—orange lichen on twigs of *Acacia sowdenii*.

*Caloplaca aurantiaca* (Lightf.) Th. Fries—encrusting dead wood.

*Parmelia* sp.—undeterminable sterile fragments.

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### References

- Adamson, R. S. and T. G. B. Osborn (1922).—On the Ecology of the Ooldea District. *Trans. Roy. Soc. S. Aust.* 46: 539-564.
- Aellen, P. (1960).—Chenopodiaceae in *Hegi, Fl. Mitteleuropa*, ed. 2, 3/2: 688.
- Anderson, R. H. (1923).—Revision of Australian Species of *Bassia*. *Proc. Linn. Soc. N.S.W.*, 48: 337-351.
- Barlow, B. A. (1963).—Studies in Australian Loranthaceae III. *Proc. Linn. Soc. N.S.W.*, 88: 137-150.
- Bibby, P. and G. G. Smith (1954).—A List of Lichens of Western Australia, *J. Roy. Soc. W. Aust.* 39: 28-29.
- Black, J. M. (1917).—Additions to Flora of S. Australia, No. 12. *Trans. Roy. Soc. S. Aust.* 41: 378-390.
- (1921).—Additions to Flora of S. Australia, No. 19. *Trans. Roy. Soc. S. Aust.* 45: 5-24.
- (1937).—Additions to the Flora of S. Australia, No. 35. *Trans. Roy. Soc. S. Aust.* 61: 241-249.
- (1943-57).—Flora of South Australia, 2nd ed., Adelaide.
- Blackall, W. E. and B. J. Grieve (1954-1965).—How to Know Western Australian Wildflowers. Perth.
- Blake, S. T. (1943).—Critical notes on the Gramineae and Cyperaceae of South Australia with descriptions of new Species. *Trans. Roy. Soc. S. Aust.* 67: 42-61.
- Burbidge, N. T. (1960).—The Australian Species of *Nicotiana* L. (Solanaceae). *Aust. J. Bot.* 8: 342-380.
- Cannon, W. A. (1921).—Plant Habits and Habitats in the arid portions of South Australia. *Carn. Inst. Wash.* 308: 81-89.
- Carolin, R. C. (1958).—The species of the genus *Erodium* L'Hér endemic in Australia. *Proc. Linn. Soc. N.S.W.* 83: 91-100.
- Chippendale, G. M. (1959).—Check list of Central Australian Plants. *Trans. Roy. Soc. S. Aust.* 82: 321-338.
- Davis, G. L. (1948).—Revision of the genus *Brachycome* Cass., Pt. 1. Australian species. *Proc. Linn. Soc. N.S.W.* 73: 142-241.
- (1952).—Revision of the genus *Calotis* R. Br. *Proc. Linn. Soc. N.S.W.* 77: 146-188.
- (1957).—Revision of the genus *Pedolepis* Labill. *Proc. Linn. Soc. N.S.W.* 81: 245-286.
- Eichler, H. J. (1965).—Supplement to J. M. Black's Flora of South Australia (2nd ed.). Adelaide.
- Gardner, C. A. (1930).—Enumeratio Plantarum Australiae Occidentalis. Perth.
- (1952).—Flora of Western Australia, I. Gramineae. Perth.
- Goodspeed, T. H. (1954).—The genus *Nicotiana*. Wal-  
tham, U.S.A.
- Hughes, D. K. (1921).—A revision of the Australian Species of *Stipa*. *Kew Bull.* 1-30.
- Hall, E. A. et al. (1964).—Regeneration of the vegetation on Koonamore Reserve 1926-1962. *Aust. J. Bot.* 12: 205-264.
- Ising, E. H. (1922).—Ecological notes on South Australian Plants, Pt. 1. *Trans. Roy. Soc. S. Aust.* 46: 583-606.
- (1964).—The species of *Bassia* All. (Chenopodiaceae) in Australia. *Trans. Roy. Soc. S. Aust.* 88: 63-110.
- Lee, A. T. (1948).—The genus *Swainsona*. *Contrib. N.S. Wales Nat. Herb.* 1: 131-268.
- Murray, B. J. (1931).—Vegetation of the Lake Torrens Plateau, South Australia. *Trans. Roy. Soc. S. Aust.* 55: 91-112.
- Osborne, T. G. B., J. G. Wood and T. B. Paltridge (1931).—On the autecology of *Stipa nitida*, a study of a fodder grass in arid Australia. *Proc. Linn. Soc. N.S.W.* 56: 299-324.
- Shaw, Elizabeth A. (1965).—A critical revision of some endemic Australian genera of Cruciferae. *Trans. Roy. Soc. S. Aust.* 89: 145-253.
- Symon, D. E. (1961).—The species of *Oxalis* established in South Australia. *Trans. Roy. Soc. S. Aust.* 84: 71-77.
- Tate, R. (1878-9).—The natural history of the country around the head of the Great Australian Bight. *Trans. and Proc. Philos. Soc. of Adel. S. Aust.* 2: 94-128.
- Verdoorn, I. C. (1954).—Newly described species. *Bothalia* 6: 415-446.
- Vickery, J. W. (1956).—A revision of the Australian species of *Danthonia* D. C. *Contrib. N.S. Wales Nat. Herb.* 2: 249-325.
- Willis, J. H. (1959).—Notes on the Vegetation of the Eucla District, W.A. *Muelleria* 1: 92-96.
- (1962).—A Handbook to Plants in Victoria 1. Melbourne.





## Obituary

### C. A. Gardner, M.B.E.

Charles Austin Gardner, former Government Botanist, and long-time member of the council of this Society, its President in 1941-42, and Gold Medalist in 1949, died at the Home of Peace, Subiaco, on February 24, 1970. After he retired in 1960, on reaching the statutory retiring age in the State civil service, he was made an Honorary Member of the Society. He was awarded the W. B. Clarke Medal of the Royal Society of New South Wales in 1961, and the Australian Natural History Medallion in 1969. In the Queen's Birthday Honours List of June 1965 he was made an M.B.E.

Charles Gardner was born in Lancaster, Lancashire, England on January 6, 1896 and in 1909 came with his family to Western Australia, where they engaged in farming at Yorkrakine. He early developed interests in botany and art, being encouraged in the former by D. A. Herbert (Economic Botanist and Pathologist at the Department of Agriculture) and Mrs. E. H. Pelloe (a leading amateur botanist of the day and authoress of *Wild Flowers of Western Australia*, 1921). In art he received formal instruction from J. W. Linton, and won a prize for a flower painting at the Perth Royal Show in 1916.

On the recommendation of Herbert, Gardner was appointed by C. E. Lane-Poole (Conservator of Forests) as a botanical collector with the Forests Department in 1920. An important event in his professional career soon after was his inclusion as botanist in the Kimberley Exploration Expedition, under Surveyor W. R. Easton, which operated in the northern Kimberleys between April and October 1921. The outcome was his impressive first botanical publication, entitled, with modest understatement, "Botanical Notes, Kimberley Division of Western Australia," published as Forests Department Bulletin No. 32 in 1923. This comprised slightly over 100 pages of detailed description of habitats and of plants, including the naming of 20 new species and several varieties. It was illustrated by photographs and the painstaking detailed drawings which were to form such a characteristic feature of most of Gardner's future publications.

He transferred in 1924 to the botanical branch of the Department of Agriculture, then in charge of W. M. Carne (Economic Botanist and Plant Pathologist). On Carne's resignation in 1928 to join the C.S.I.R. the botanical section was re-organized and Gardner became Government Botanist and Curator of the State Herbarium; the plant pathology work of the Department becoming the responsibility of H. A. Pittman.

In his new post Gardner travelled widely over the State, adding to the collections of the State Herbarium and producing numerous

taxonomic papers, an important series, "Contributions to the Flora of Western Australia," beginning in the *Journal* of this Society in 1923. Altogether he described 8 new genera and some 200 new species. His experiences in the Kimberley expedition of 1921 stimulated a life-long interest in problems of plant distribution, which formed the subject of his presidential address to the Society in 1942.

In 1930 he published a systematic census of Western Australian plants, *Enumeratio Plantarum Australiae Occidentalis*, as a preliminary to an intended Flora of the State. However beyond a volume on the grasses (1952) and a joint work with H. W. Bennetts on the poison plants (1956) this did not proceed far in publication. Before his death he had been working on books on the genus *Banksia* and the genus *Eucalyptus*. He published numerous articles on the forest formations of Western Australia in the *Australian Forestry Journal* and on various botanical subjects in the *Journal of the Department of Agriculture*, culminating with a long series of over a hundred items on the *Eucalyptus* trees of Western Australia. Several popular books, illustrated in part by the water-colours of Edgar Cell, were published by West Australian Newspapers Ltd. The final one, in handsome format, *Wildflowers of Western Australia*, appeared in 1959.

In 1937 Gardner was stationed at the Royal Botanic Gardens, Kew, as the first Australian botanical liaison officer. Between 1924 and 1962 he delivered courses of lectures on plant geography and systematic botany in the Faculty of Agriculture of the University of Western Australia. He served as a member of the State Gardens Board (later National Parks Board), and, in later years after retirement, as honorary consulting botanist to the King's Park Board.

As a conservationist his achievements were notable and he was instrumental in persuading the Government to proclaim the following five extensive flora reserves: (1) at the lower Murchison River; (2) the Hill River Reserve (Mt. Lesueur); (3) the reserve south of Southern Cross (Lake Cronin); (4) the area between the Gairdner River and the Hamersley River (including the Barren Ranges); and (5) the area between Cape Arid and Israelite Bay.

A list of his writings, covering some 320 items between 1923 and 1962, is filed at the Department of Agriculture, the Battye Library in the State Library, the Botany Department of the University, and at the Royal Botanic Gardens, Melbourne.





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